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Something strange is
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Are prescription
WEIGHT-LOSS DRUGS SAFE?

THE HUNT FOR ULTRAMASSIVE BLACK HOLES

What happens when these cosmic monsters reach their limits?

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FROM THE EDITOR

Are there really dinosaurs in fossil fuels? →p78

Spaghettification. It's the term that describes what would happen if you fell feet-first into a black hole. You'd be stretched out and squeezed in at the same time, quickly turning you into something that resembles a human noodle. This happens because the difference in the strength of gravity between your feet and your head as you approach the black hole is so great. Its pull would be enough to yank your ankles out away from you, and its pressure would push your sides inwards, turning your body into the sort of shape you'd expect to find in a bowl of bolognese. Thankfully, it hasn't happened to a human yet (as far as we know), but we have seen it happen to stars as they get dragged into the all-consuming maw of a black hole.

Why mention this grisly process? Well, because it's a fact that epitomises why we find black holes so fascinating. They're unreal, to the point of being cartoonish. Everything we learn about them seems to defy logic. They crush entire galaxies to an infinitely small point. They slow time down the nearer you get to them. And despite their reputation for being insatiable agents of destruction, they happily sit at the heart of most galaxies, which suggests they might be involved in their creation.

And here's a new one: it might be possible for a black hole to be fully satiated. The very biggest of them – the ultramassive black holes – might not be the bottomless pits that we think. What's more, these ultramassive black holes could already be out there, enjoying a completely invisible retirement after having eaten their fill. To find out more, head to p52.

Daniel Bennett

Daniel Bennett, Editor

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DR REBECCA SMETHURST

Known as Dr Becky to her YouTube subscribers, Rebecca is an astrophysicist who studies black holes. She sheds light on how they grow. →p52

KIMBERLEY WILSON

A psychologist and former *Great British Bake Off* finalist, Kimberley studies food's effect on us. She explores the link between processed foods and mental health. →p66

PROF GILES YEO

Giles is one of the presenters of the BBC's *Trust Me, I'm A Doctor*. Find out what he makes of the 'anti-obesity' jab that's coming to the UK. →p30

SUSANNE WEDLICH

Susanne is a science journalist for *Der Spiegel* and *National Geographic*. She dives into the slippery world of slime to discover why it's so important to all life on Earth. →p60

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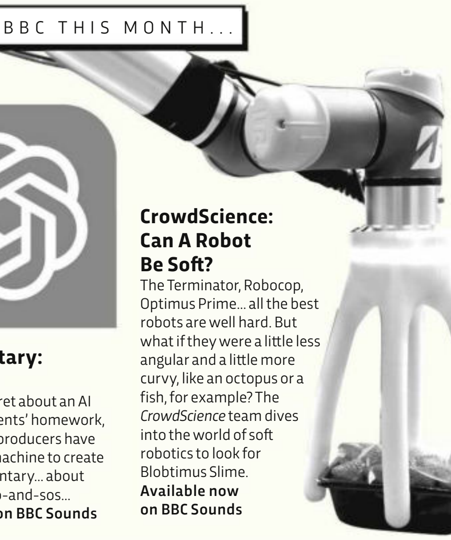
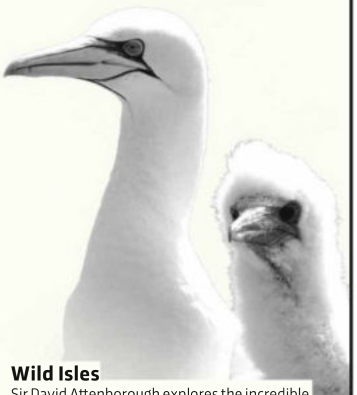
ON THE BBC THIS MONTH...

A Documentary: By ChatGPT
While teachers fret about an AI that can do students' homework, the BBC Radio 4 producers have gone and got a machine to create a whole documentary... about itself. The lazy so-and-sos...
Available now on BBC Sounds



CrowdScience: Can A Robot Be Soft?
The Terminator, Robocop, Optimus Prime... all the best robots are well hard. But what if they were a little less angular and a little more curvy, like an octopus or a fish, for example? The *CrowdScience* team dives into the world of soft robotics to look for Blobtimus Slime.
Available now on BBC Sounds



Wild Isles
Sir David Attenborough explores the incredible wildlife here in Britain and Ireland. This six-part series will get up close and personal to some of the most dramatic wildlife you can find on our shores, from battling butterflies to killer whales on the hunt.
BBC One
Starts in spring (check *Radio Times* for details)
Also available on iPlayer

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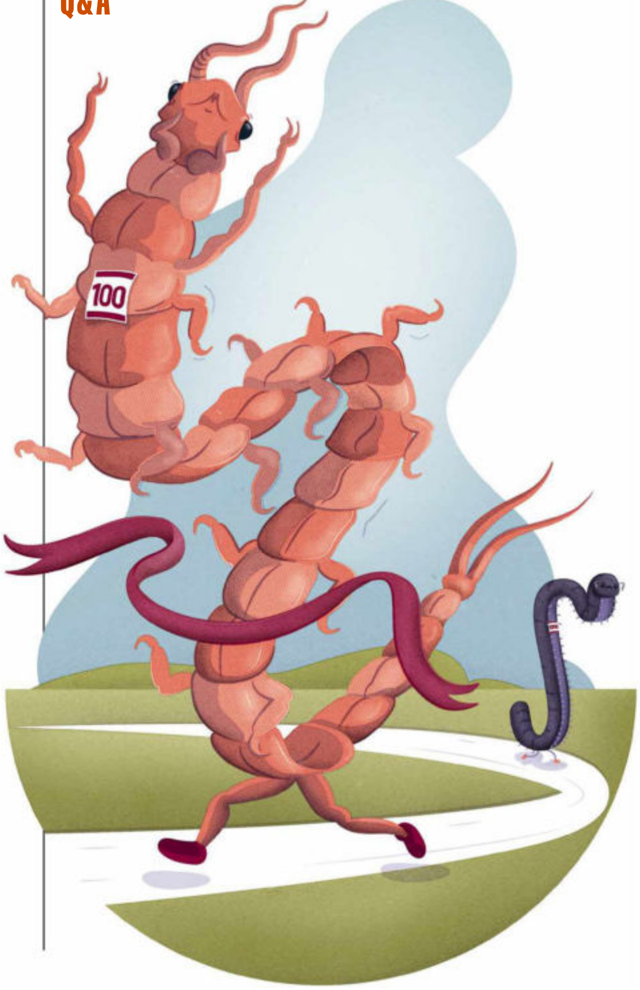

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Slime is everywhere, and without it, life on Earth would probably not exist. Let us tell you the glorious story of goo. Now, once upon a slime...

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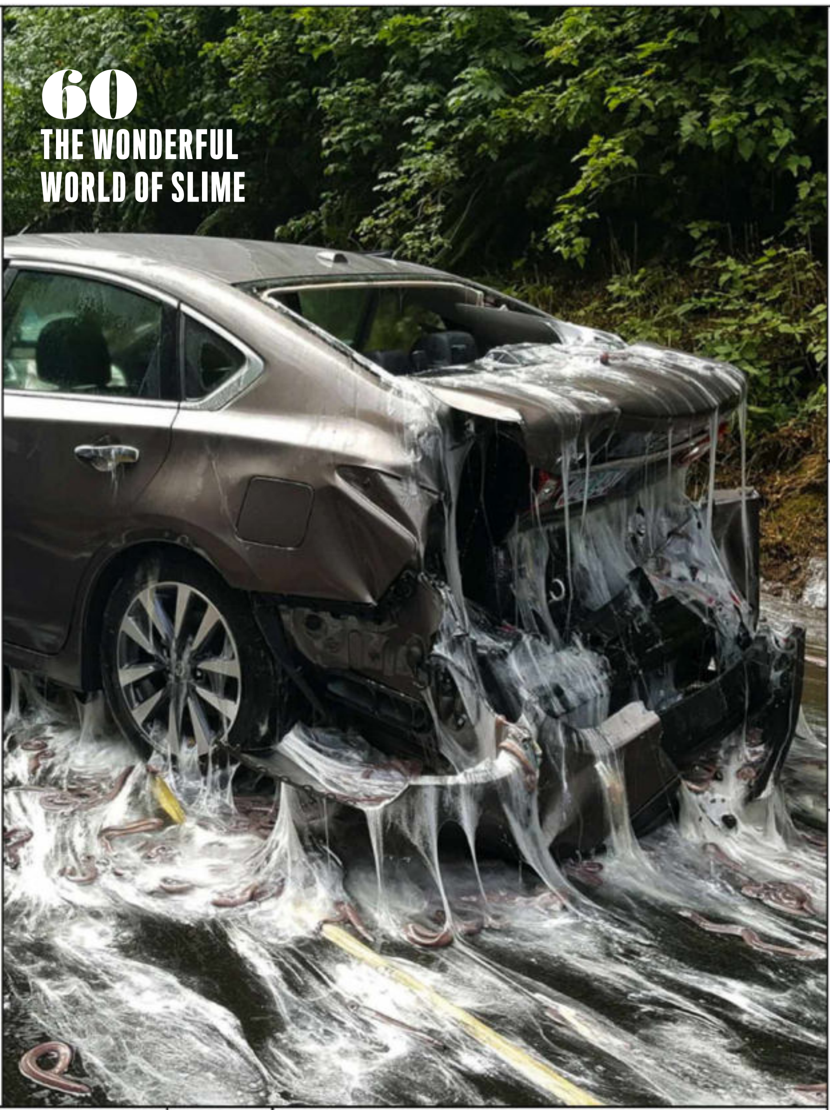
Ultra-processed foods are tasty and convenient, but by filling up on them, we are robbing our bodies and brains of the nutrients that can keep us healthy and happy.



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THE HUNT FOR ULTRAMASSIVE BLACK HOLES
SF

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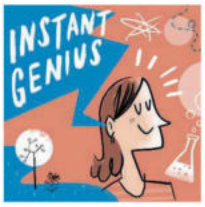

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We test out the Meta Quest Pro.

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DR ARIK KERSHENBAUM

×

"WE WILL FIND LIFE ON OTHER PLANETS. IT WILL HAPPEN SOON AND IT'S GOING TO BE SLIME"

EYE OPENER

Eye in the sky

BURSA, TURKEY

On 19 January, this weird, UFO-shaped cloud appeared over the city of Bursa at sunrise. This type of rare formation is a 'lenticular cloud' and tends to occur in the troposphere, which is the lowest layer of Earth's atmosphere. According to the Met Office, when moist, stable air blows across a large obstacle, such as a mountain range, a series of ripples can form. If conditions are right, the water vapour in the rippled air may condense to form lenticular clouds. Turbulence can accompany the clouds, so pilots tend to avoid them – unless they particularly enjoy bumpy conditions!

As lenticular clouds do not generally form over flat ground, many people have never seen them. In fact, it's thought that a number of UFO sightings can be attributed to the clouds, thanks to their flying-saucer shape. To further add to their unusual appearance, lenticular clouds can sometimes exhibit patches of colourful iridescence, because of the way that water droplets within them scatter light.

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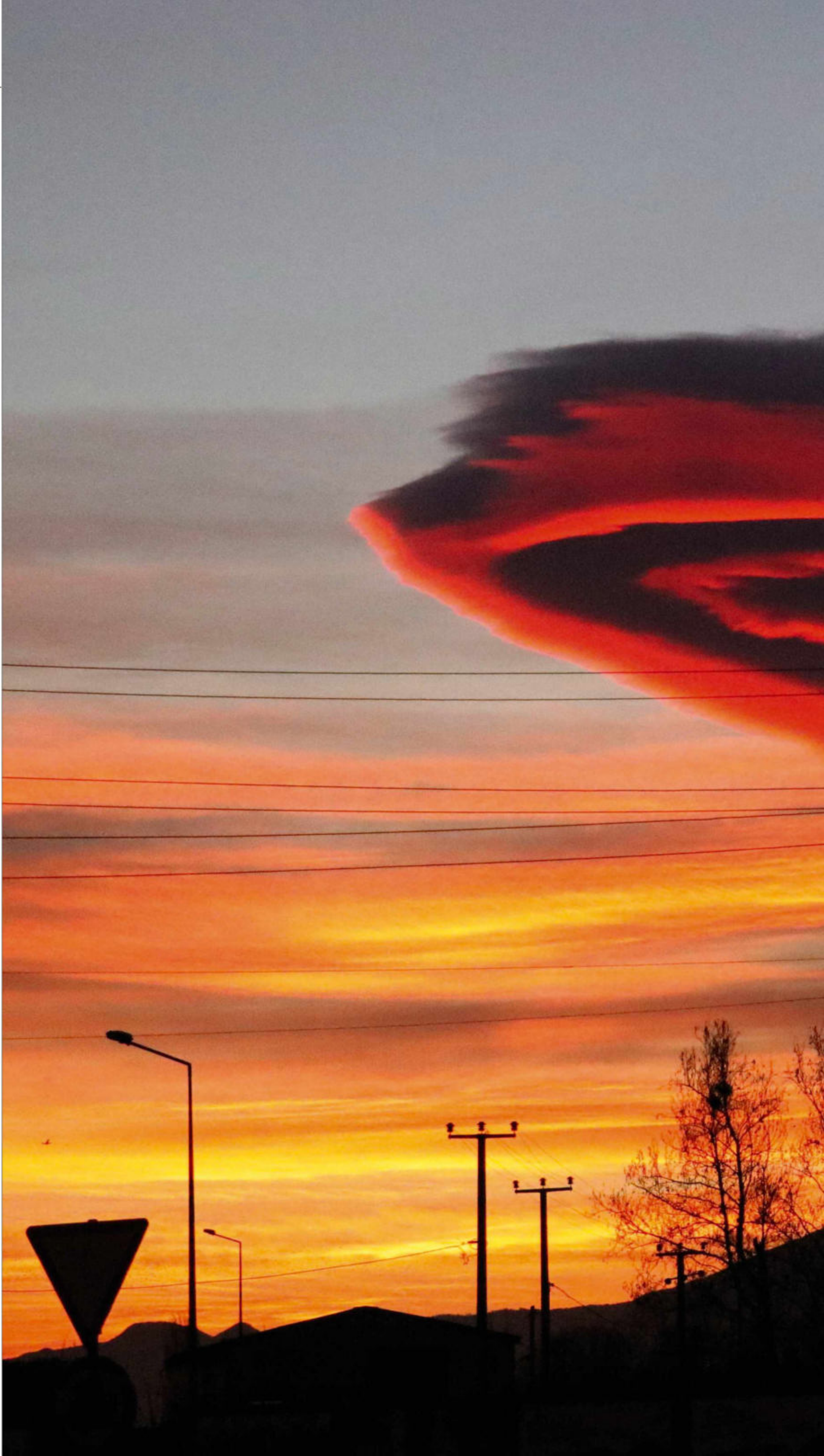

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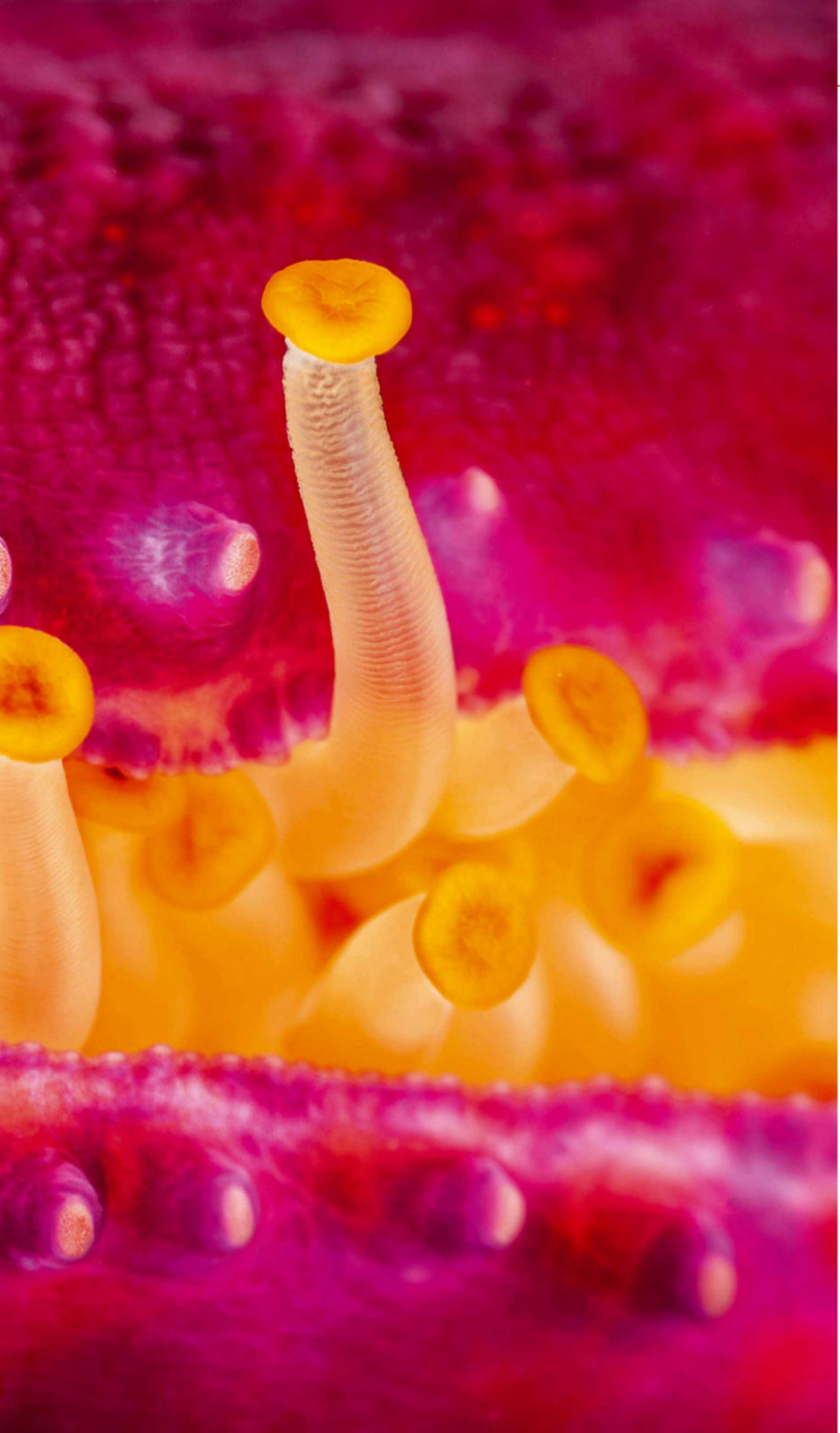

EYE OPENER

Small but mighty

MAUI, PACIFIC OCEAN

Seen here are the delicate and flexible tube feet on the underside of a Leach's sea star (*Leiaster leachi*). Tube feet are unique to echinoderms – that's the group that includes starfish, sea urchins, sea cucumbers and brittlestars – and are operated via a water vascular system, which uses increasing and decreasing water pressure to extend and contract the appendages. In this way, a starfish can propel itself across the seabed, releasing and reattaching the tube feet in a coordinated fashion, creating a mesmerising pattern of motion.

Yet despite their gentle appearance, tube feet are also a formidable weapon, especially when it comes to food. When a starfish detects a potential snack, the tube feet move swiftly and efficiently to pull an unsuspecting victim into a tight embrace. The tube feet hold tight to prevent escape, and the starfish can chow down; but not before digestive enzymes turn the prey's tissues into a more palatable soupy mixture. Yum.

DAVID FLEETHAM/NATUREPL.COM

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EYE OPENER

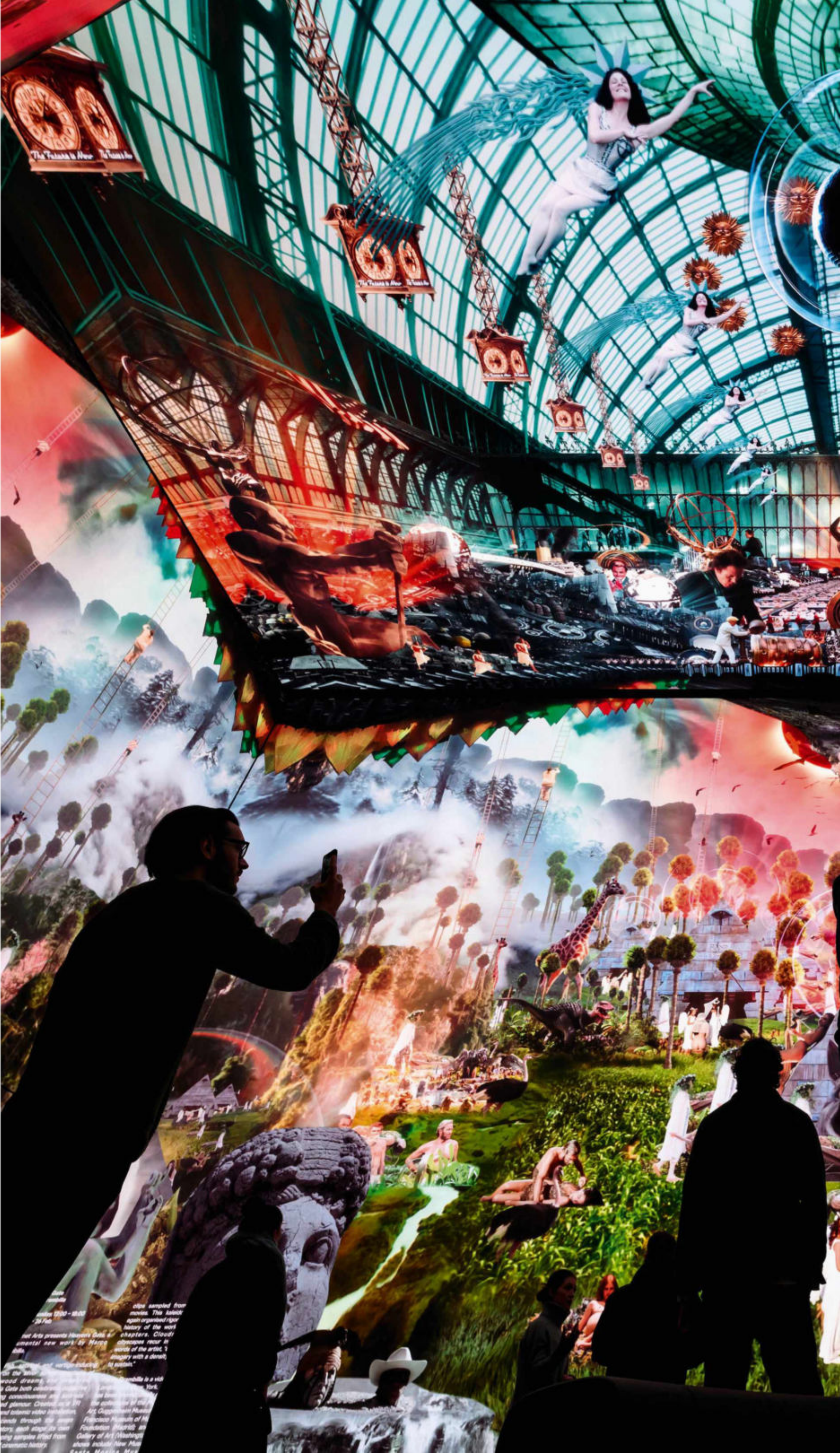
Think your TV is big?

LONDON, UK

Ever wondered what it might be like if your TV was expanded to Sistine Chapel proportions? Probably not. But if you did, it might look something like this.

What you're seeing here is the inside of the Now Building, a public atrium in London's Soho district that's been lined with 8K LED screens to create a giant digital canvas. How giant? Well, the atrium stands four storeys tall and is covered from floor to ceiling with 2,100m^2 (23,000ft^2) of HD TV screens. Outernet London, the company behind the Now Building, describes it as the "largest LED screen deployment by pixel density on the planet".

The hundreds of millions of pixels in these screens have been deployed to broadcast an immersive mix of digital artworks, entertainment and advertising. The image being shown in this shot is Heaven's Gate, a panoramic video collage created by the artist and director Marco Brambilla, featuring psychedelic landscapes made up of looping samples of iconic moments in cinematic history.



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CONVERSATION

YOUR OPINIONS ON SCIENCE, TECHNOLOGY AND *BBC SCIENCE FOCUS*

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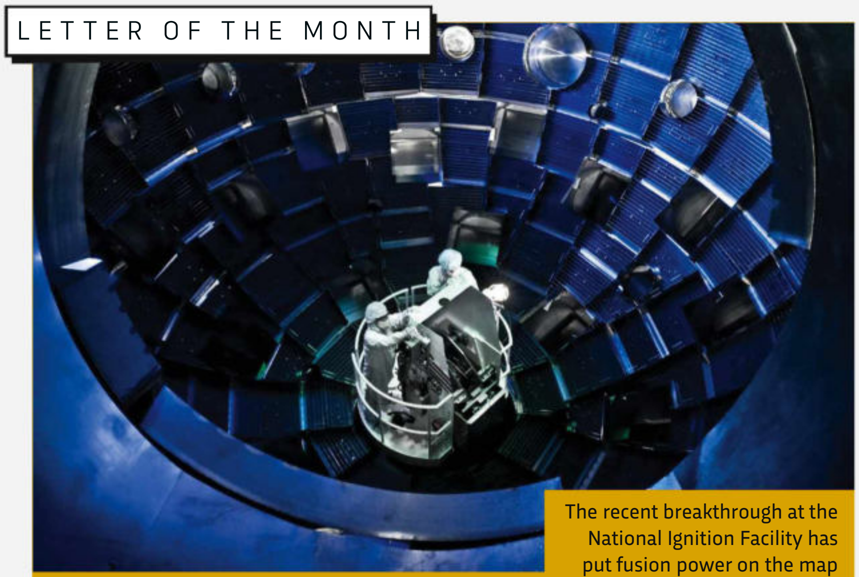
LETTER OF THE MONTH



The recent breakthrough at the National Ignition Facility has put fusion power on the map

Always 30 years...

I have keenly followed nuclear fusion research for over 30 years and, as the old joke goes, it's always been just 30 years away, so I'd have hoped to have working fusion reactors by now! Therefore, I was thoroughly pleased when I heard about the breakthrough at the National Ignition Facility at the Lawrence Livermore National Laboratory in the US (January, p14), where 'ignition' has been achieved for the first time. The holy grail has been to get a net gain of energy and when it came, I expected it to be very small. But it was huge, with 2.05 megajoules hitting the target hydrogen isotopes and 3.15 megajoules being released. Some critics will say that, in reality, with 300 megajoules of power going to the laser, the actual gain is only 0.15 megajoules, but even this is an amazing result. And now it's been proven to work, we can hopefully increase the efficiency of the process and scale it up. I look forward to seeing commercial fusion power, hopefully in less than 30 years!

Luke Russell, Tingley

WRITE IN AND WIN!

The writer of next issue's *Letter Of The Month* wins ***The Secrets Of Life* quartet** from Otium Press, including *How Did Life End Up With Us? How Did We Get To Be So Different? Why Do We All Behave In The Way We Do?* and *So What Does It All Mean*? Once you start reading these, you'll be able to find out the answers to all those important questions! **otiumpress.com**

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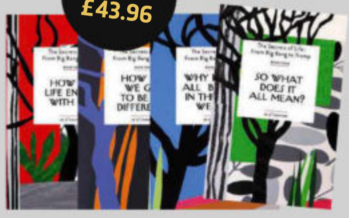
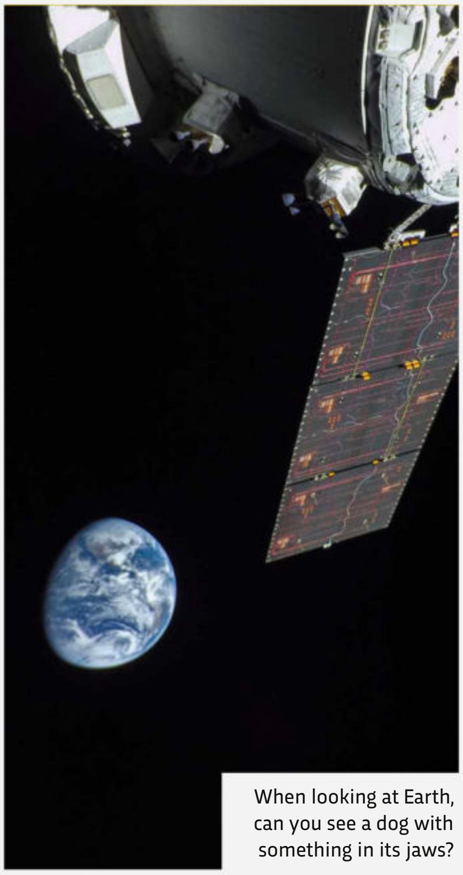


A dog's face in the clouds

The January issue of *BBC Science Focus* contained two photos that intrigued me. One was the limpet (p8) and the other was Earth from space (p6). We often see faces or other objects in the clouds while doing things like relaxing or sunbathing. I was doing neither, but I thought the limpet looked like a portly, shirtless man blowing bubbles while smiling broadly! Then, when I looked at the Earth from space image in portrait mode, I could clearly see a dog holding something in its jaws! Did anyone else see this?

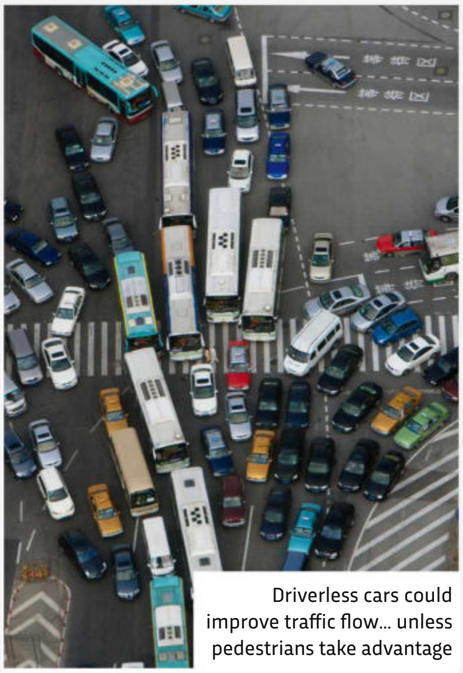
Chris Stracey, Poole



When looking at Earth, can you see a dog with something in its jaws?

“THE FACT THAT MEASURABLE BRAIN DAMAGE CAN BE INDUCED BY JUST A FEW DAYS ON A DIET THAT MANY PEOPLE EAT HABITUALLY IS CONCERNING”

KIMBERLEY WILSON, P66



Driverless cars could improve traffic flow… unless pedestrians take advantage

More traffic jams?

To continue the conversation around driverless cars (November, p44), a recent podcast by *Philosophise This!* postulated that driverless cars may completely reverse the power dynamic between pedestrians and vehicles. Once people realise that the cars will stop for them, then pedestrians will wander across streets creating jams filled with deferring, cautious vehicles. So, driverless traffic will need dedicated lanes to proceed smoothly, ironically turning them into the trams of yore.

Bill Maryon, Bristol

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FOLLOW THE CONVERSATION

TWEETS FROM READERS AND EXPERTS

@theRAD_lab

(Rebecca Drummond)

I had a lovely chat about all things fungi and fungal infections in the latest BBC @sciencefocus *Instant Genius* podcast. Check it out here: **bit.ly/fungal_infections**

@aes_2fish

From the birth of our Solar System, up until its eventual, flashy disintegration in our atmosphere, [asteroid] #Sar2667 has been with us, quietly. What luck to have witnessed this and been able to capture it :)

Asteroid #Sar2667, snapped by @aes_2fish

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ADVERTISEMENT FEATURE

SHINING A LIGHT ON LEPROSY

In many countries, people with leprosy are overlooked. Thankfully, support is out there.

lepra

We will beat
leprosy together

Breaking the cycle of prejudice

In many countries, people with leprosy are overlooked. Thankfully, support is out there.

Leprosy may have been around for almost 3,500 years, but it is a disease that is all too often misunderstood. Leprosy is a chronic, infectious disease caused by a bacteria called *Mycobacterium leprae*.

Through time, the disease has travelled around the globe, impacting almost every region in the world. To this day, there is still much that remains unknown about its transmission, but huge strides forward have been made in the understanding and treatment of the disease. Along with understanding the complexities of the disease, a greater awareness of leprosy is needed to secure longer-term support for community healthcare and research, to improve not only effective detection but also treatment.

Lepra's approach to active case finding

Founded in 1924, Lepra is a UK-based charity working with networks of people affected by leprosy in India and Bangladesh, offering early case detection, treatment, ongoing support and training for local healthcare workers. Lepra's community self-support groups are playing an increasingly important role in early case detection. Members of the community are often able to offer valuable support, providing informal education and building trust with people in remote and rural areas, helping 'active case finding' (ACF) teams to locate and refer potential new cases at an even earlier stage. The key feature of ACF is finding possible cases and referring them to a specialist who is able to diagnose cases using a slit-skin-smear test. Upon diagnosis, antibiotics are then administered to treat the disease, while other medicines can be prescribed for reactions, nerve inflammation and any other complications that may occur.

Lepra Mental Motivator Project

One thing which is often overlooked is the mental strain that comes with a leprosy diagnosis. Mental health issues have long been synonymous with people affected by leprosy, with over half of people with newly diagnosed cases of leprosy developing anxiety and depression. This is why Lepra's projects such as Mental Motivators have become so valuable. Lepra supports the social and psychological impacts of the disease and provides training to grassroots health providers. This project aims to directly help people affected by leprosy, ensuring they have equal and easy access to public and private health services. In turn, we will see improved mental health services so that people will feel supported in improving and managing their wellbeing.

Shine a light on leprosy in 2023

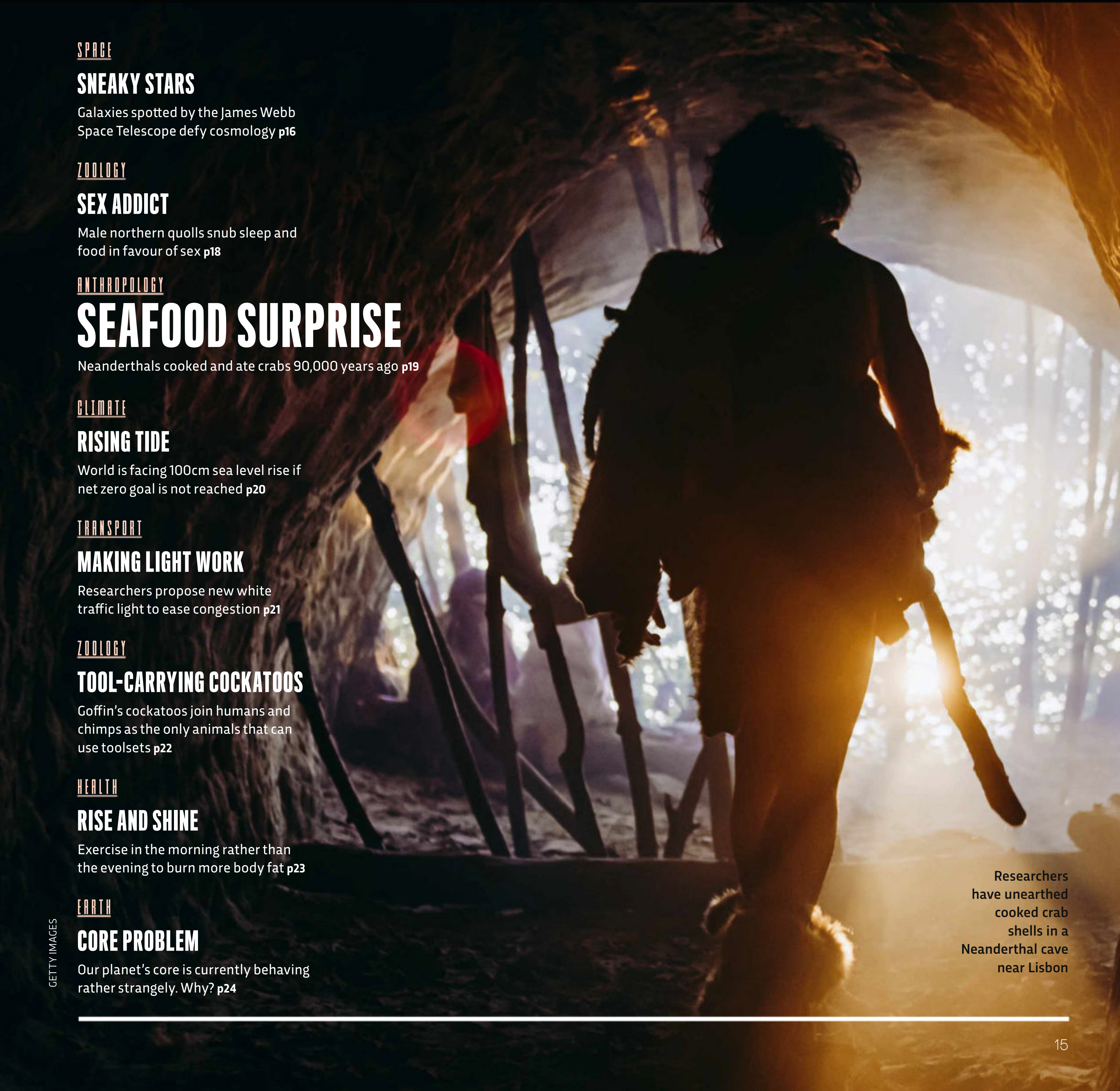
Lepra is focusing on person-centred treatment and research programmes in isolated and hard-to-reach communities in India and Bangladesh. Lepra not only supports the health of people affected by leprosy but also understands the social and psychological impacts of the disease. The charity will be providing training to grassroots health providers and raising awareness to break down the myths about leprosy that still prevail.

This year, Lepra is asking people to help 'shine a light on leprosy' by pledging a positive action to raise awareness of this forgotten disease. This could be done by visiting the New Face Of Leprosy exhibition with friends or family, or perhaps by signing up for the Lepra newsletter. You can even book a free Lepra talk in local schools and places of worship.

To make a positive action pledge for World Leprosy Day 2023, or to find out more about Lepra's work, visit:

> “If we miss this emissions goal, the ice sheets will disintegrate and melt”
>
> Prof Axel Timmermann **p20**

DISCOVERIES



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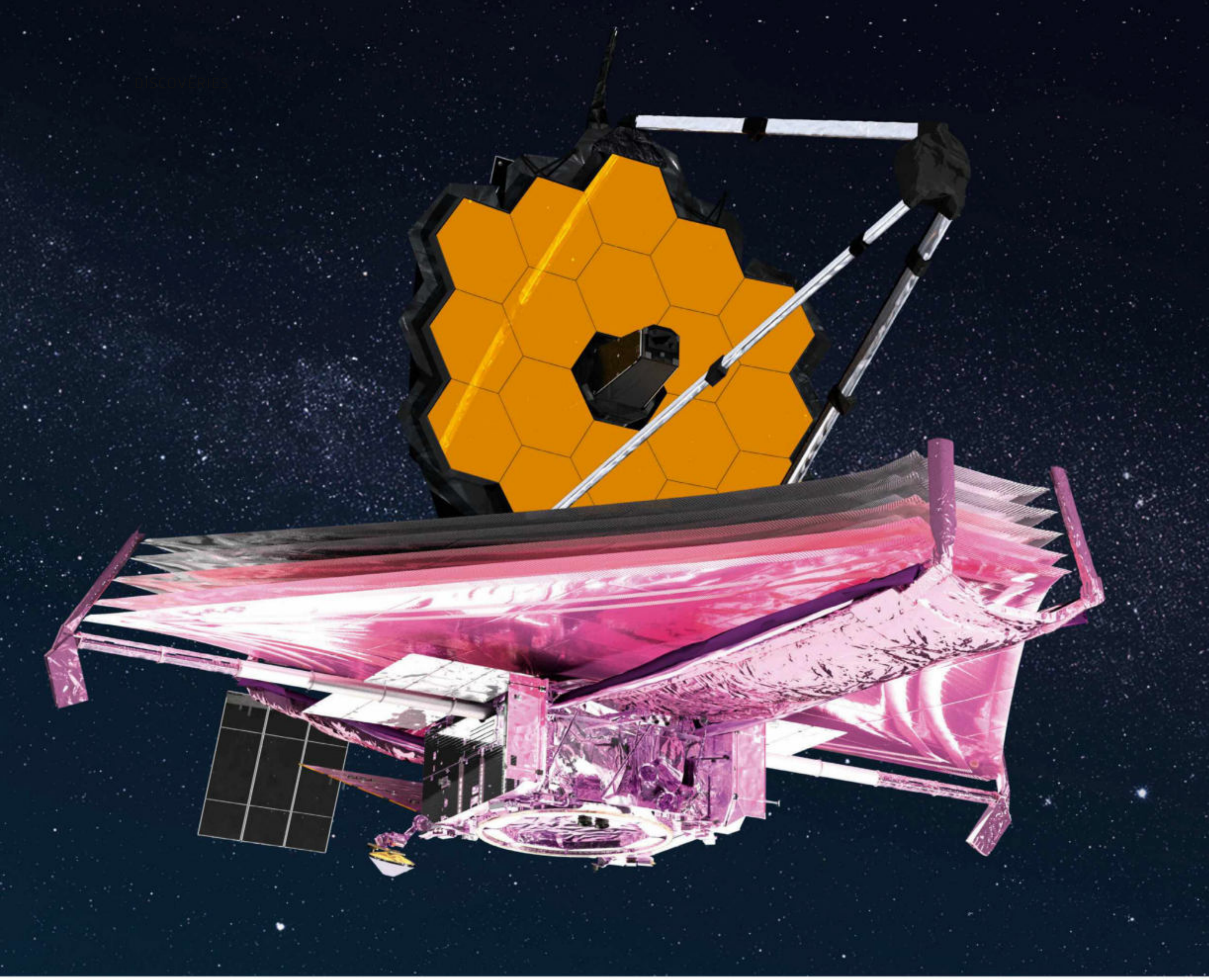
Researchers have unearthed cooked crab shells in a Neanderthal cave near Lisbon

GETTY IMAGES



SPACE

THE JWST HAS UNEARTHED EVIDENCE OF ANCIENT GALAXIES THAT SHOULDN'T EXIST

The presence of such massive galaxies lurking in the early Universe contradicts current cosmological models

An international team of astrophysicists have found six candidate galaxies hiding in data from the James Webb Space Telescope (JWST) that are so old and massive they can't be explained by current cosmological models.

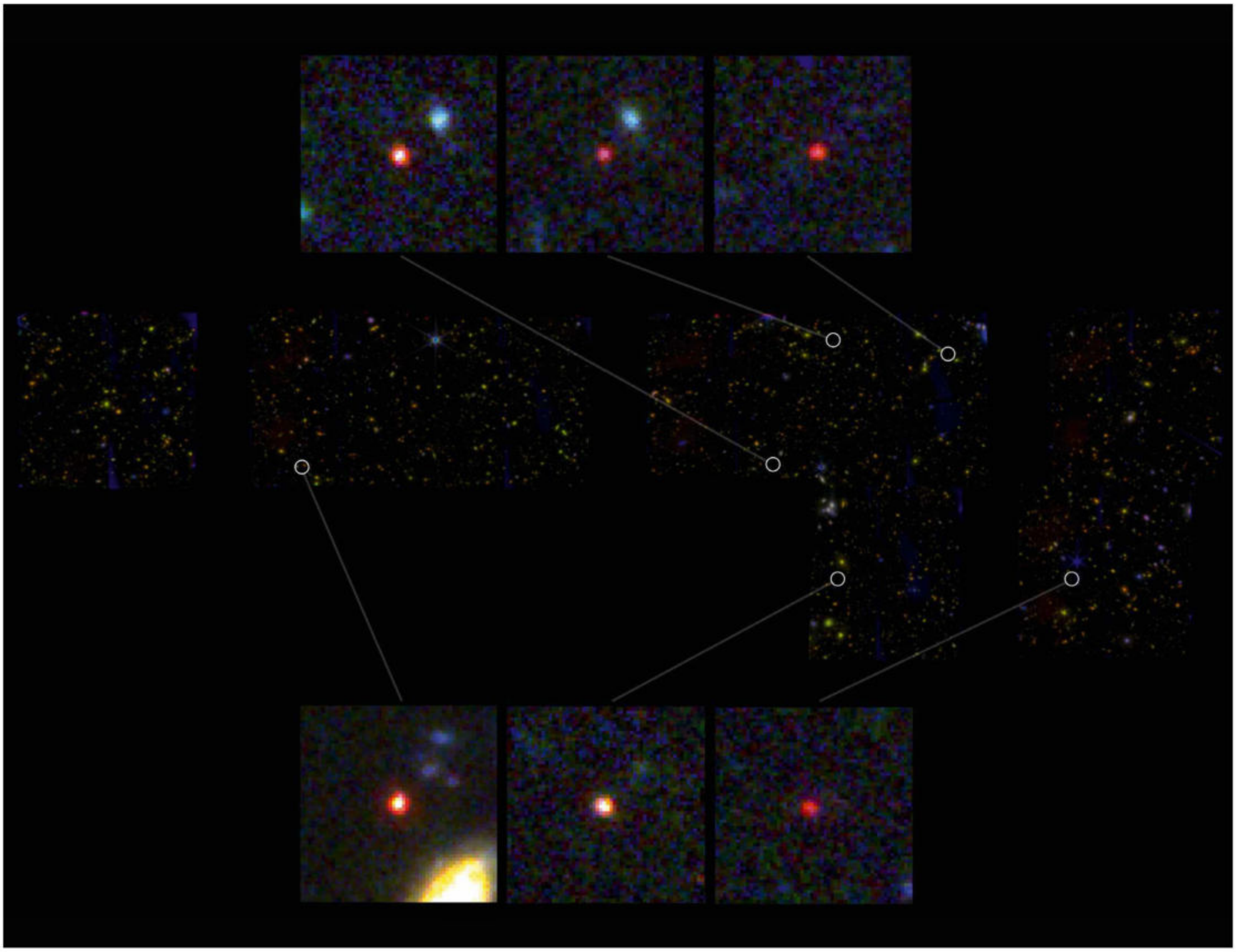
The galaxies are thought to date back to around 500 million years after the Big Bang, more than 13 billion years ago. According to current cosmological models, galaxies at this point in time should be in their infancy and be made up of only a few stars.

However, all six of the newly discovered candidate galaxies are gigantic and contain a similar number of stars to the modern-day Milky Way.

"It's bananas," said co-researcher Erica Nelson, assistant professor of astrophysics at the University of Colorado Boulder. "You just don't expect the early Universe to be able to organise itself that quickly. These galaxies should not have had time to form."

The team discovered the candidate galaxies among images released by the JWST's recent Cosmic Evolution

ABOVE The James Webb Space Telescope, as seen in this artist's impression, is studying objects too old, distant or faint for Hubble to detect



NASA/JOHNSON SPACE CENTRE, NASA/ESA/CSA/I LABBE/G BRAMMER

ABOVE Images of the six candidate galaxies, seen 500-800 million years after the Big Bang. The one on the bottom left could contain as many stars as the Milky Way, but is 30 times more compact

“It’s bananas. You don’t expect the early Universe to organise itself that quickly”

Early Release Science (CEERS) survey – one of the telescope’s initial run that saw it peering deep into a patch of sky near to the famous Plough asterism.

Nelson was poring over the images when a few unusual fuzzy dots caught her eye. The dots were red, an indication that they were from old sources of light. This is due to the expansion of the Universe stretching out the light emitted from celestial objects, increasing their wavelengths and making them appear more red.

After running a number of calculations, the researchers dated the candidate galaxies back to just over 13 billion years ago and determined that they were home to tens to hundreds of billions of Sun-sized stars’ worth of mass. This means that they would’ve had to form stars at an astonishing rate due to their short lives.

“The Milky Way forms about one to two new stars every year,” said Nelson. “Some of these galaxies would have to be forming hundreds of new stars a year for the entire history of the Universe.”

The researchers now intend to further study the mysterious cosmic objects using the JWST in order to confirm or disprove that they date so far back in time and contain as many stars as their preliminary observations suggest. However, these initial results offer a tantalising taste of how the JWST could already be rewriting astronomy textbooks, they say.

“If even one of these galaxies is real, it will push against the limits of our understanding of cosmology,” said Nelson.

ZOOLOGY

ENDANGERED MALE QUOLLS ARE CHOOSING SEX OVER SLEEP – AND IT MAY BE KILLING THEM

The finding could explain why males usually only survive for one mating season, while females can live through several

The habit of male northern quolls to forgo sleep and food in favour of recklessly pursuing every possible mating opportunity may be killing them, researchers from the University of the Sunshine Coast, Australia, have found.

Northern quolls (*Dasyurus hallucatus*) are carnivorous cat-sized marsupials that live across northern Australia. While the females can live and reproduce for up to four years, the males rarely make it beyond a single mating season. The reason for this has long puzzled researchers.

Now, a new study suggests that this post-breeding die-off, known as semelparity, may be due to males travelling long distances and skipping sleep in order to mate with as many females as they can.

“They cover large distances to mate as often as possible and it seems that their drive is so strong that they forgo sleeping to spend more time searching for females,” said co-researcher Dr Christofer Clemente, senior lecturer in animal ecophysiology.

“Something is definitely causing their health to fail after just one season and we think it’s linked to sleep deprivation. The dangers of a lack of sleep are well documented in rodents, and many of the traits associated with sleep deprivation we see in male quolls, and not in females.”

The team followed the activity of wild roaming male and female northern quolls on Groote Eylandt, off the coast of the Northern Territory, Australia, by fitting them with tracking backpacks.

They found that males spent less time sleeping and resting than females and travelled over greater distances.

“Two males, who we named Moimoi and Cayless moved for 10.4km and 9.4km in one night, respectively. An equivalent human distance, based on average stride length, would be around 35 to 40km,” said lead researcher Joshua Gaschk.

In addition, the team found that the males’ condition deteriorated because they were devoting less time to grooming and clearing themselves of parasites. They also lost weight, as they were skipping meals.

The researchers now want to determine if sleep deprivation is experienced by other marsupial mammals such as opossums, marsupial mice and Tasmanian devils.

MARSUPIALS IN NUMBERS

334
The number of living species of marsupials in the world.

70
The percentage of marsupial species that are found on the Australian continent. The remaining 30 per cent are found in the Americas.

6 GRAMS
The weight of the long-tailed planigale, the smallest marsupial species. The largest, the red kangaroo, can grow up to 90kg.

BELOW “Quick, run, run, run, mate, run, now, mate, quickly, quickly!” Male northern quolls live life in the fast lane, with no time for food or sleep

JIRI LOCHMAN/NATUREPL.COM, GETTY IMAGES

ANTHROPOLOGY

NEANDERTHAL GOURMETS REGULARLY FEASTED ON ROASTED CRAB

The discovery of cooked crab shells in a Lisbon cave is further evidence that the early hominids had a sophisticated culture

While once thought to be lumbering, slow-witted brutes, evidence has mounted over the past decade that the Neanderthals had a rich culture. They were capable hunters and toolmakers, created art and ate a varied diet that included cooked food.

Now, researchers from Spain's Catalan Institute of Human Paleoecology and Social Evolution (IPHES-CERCA) have found further evidence of our closest relatives' cooking skills and discerning palates. They visited Portugal's Gruta da Figueira Brava cave, which Neanderthals were known to inhabit, and unearthed charred shells of brown crabs that date back 90,000 years.

"At the end of the last interglacial, Neanderthals regularly harvested large brown crabs," said lead researcher Dr Mariana Nabais of IPHES-CERCA. "They were taking them from pools of the nearby rocky coast, targeting adult animals with an average carapace [upper shell] width of 16cm. The animals were brought whole to the cave, where they were roasted on coals and then eaten."

Upon examining the leftover shells and claws, the researchers estimated that the crabs were mostly large adults that contained around 200g of meat. The lack of scratches or marks on the shells rules out the possibility that they were eaten by rodents or birds, and so were likely harvested by the Neanderthals from tide pools in the summer, they say.

In addition, black burn marks on the shells indicate that they were heated up to somewhere between 300°C and 500°C, a common, if slightly high, temperature for cooking over flames.

The finding also casts doubt on the theory that the consumption of seafood helped early *Homo sapiens*' brains to develop more quickly than those of Neanderthals.

"Our results add an extra nail to the coffin of the obsolete notion that Neanderthals were primitive cave dwellers who could barely scrape a living off scavenged big-game carcasses," said Nabais.

"Together with the associated evidence for the large-scale consumption of limpets, mussels, clams, and a range of fish, our data falsify the notion that marine foods played a major role in the emergence of putatively superior cognitive abilities among early modern human populations of sub-Saharan Africa."

CLIMATE

WORLD FACING IRREVERSIBLE AND CATASTROPHIC CONSEQUENCES IF NET ZERO CARBON NOT REACHED BY 2060

Computer models show melting ice sheets in Greenland and Antarctica could cause 100cm of sea level rise in the next 130 years

According to the World Economic Forum, up to 410 million people could be at risk from coastal flooding in the next 100 years as climate change continues to cause global sea levels to rise.

Melting ice sheets are a major contributor to rising sea levels, but it is notoriously difficult to predict their precise effect as the physics governing their behaviour is extremely complex. Now, a team of researchers from the IBS Center for Climate Physics in Busan, South Korea, have produced a computer simulation that models the complex interplay between the ice sheets, icebergs, the oceans and the atmosphere for the first time.

The model predicts that melting ice sheets in Greenland and western Antarctica could create a runaway effect in sea level rises that can only be averted if the world reaches net zero carbon emissions before 2060.

"If we miss this emissions goal, the ice sheets will disintegrate and melt at an accelerated pace, according to our calculations. If we don't take any action, retreating ice sheets would continue to increase sea levels by at least 100cm within the next 130 years. This would be on top of other contributions, such as the thermal expansion of ocean water," said Prof Axel Timmermann, part of the research team and the director of the IBS Center for Climate Physics.

The study highlights the imminent need for more sophisticated supercomputer-based climate models that are capable of taking into account all of the disparate components that contribute to sea level rise, the researchers say.

"One of the key challenges in simulating ice sheets is that even small-scale processes can play a crucial role in the large-scale response of an ice sheet and for the corresponding sea-level projections," said Timmermann.

NASA/GSFC, GETTY IMAGES

TRANSPORT

A FOURTH 'WHITE' TRAFFIC LIGHT WOULD HELP DRIVERLESS CARS TO EASE CONGESTION, SCIENCE SAYS

The extra light would indicate that autonomous vehicles had taken over control of the traffic flow at busy junctions

Adding an extra light to traffic lights to show when autonomous vehicles (AVs) are taking control of the traffic to keep it moving, could ease congestion, according to simulations run by engineers at North Carolina State University.

The proposed four-light system would operate in the same way as the current three-light systems – red means stop, green means go, and so on. However, if a threshold number of driverless cars is detected approaching an junction, the white light phase is triggered, overriding the three-light system.

The white light signals to human drivers in non-autonomous cars that self-driving cars have taken control of the traffic flow and are coordinating their movements via wireless communication. Any cars being driven by a human are then simply required to follow the car in front – if the car in front stops, they stop; if the car in front goes through the junction, they follow. The driverless cars don't need to 'look' at the white light, as they'll be communicating with it wirelessly.

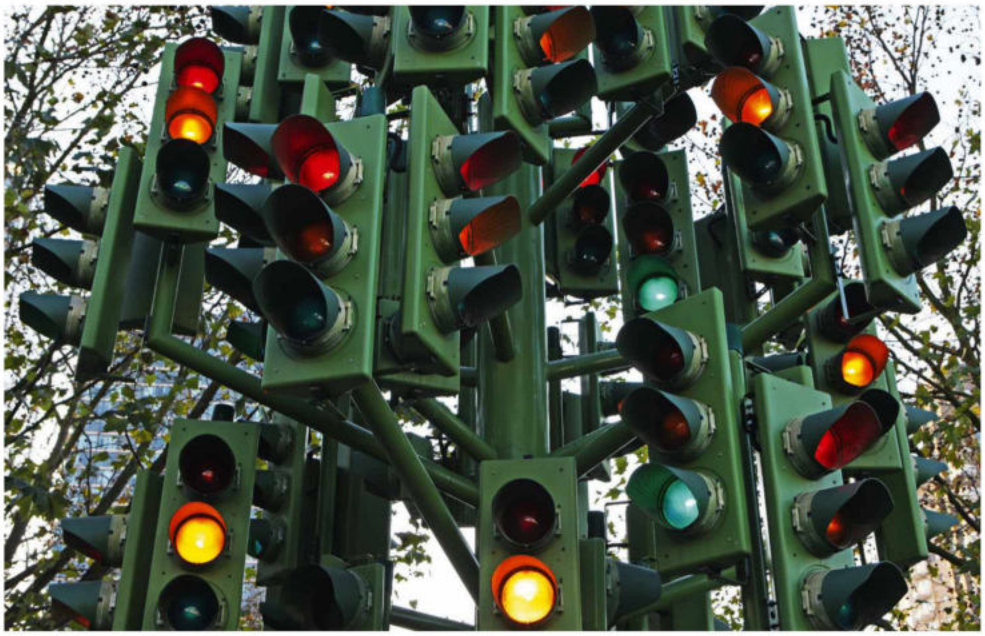
"This concept we're proposing for traffic intersections, which we call a 'white phase,' taps into the computing power of AVs themselves," said co-researcher Dr Ali Hajbabaie, an associate professor of civil, construction and environmental engineering at North Carolina State.

"Granting some of the traffic flow control to the AVs is a relatively new idea, called the 'mobile control paradigm'. It can be used to coordinate traffic in any scenario involving AVs. But we think it is important to incorporate the white light concept at intersections because it tells human drivers what's going on, so that they know what they're supposed to do as they approach the intersection. And, just to be clear, the colour of the 'white light' doesn't matter. What's important is that there be a signal that's clearly identifiable by drivers."

The simulations found that small improvements in traffic flow occurred when as little as 10 per cent of the vehicles at an intersection were autonomous. And as the percentage of AVs increased, so too did the traffic flow.

"Even if only 10 per cent of the vehicles at a white phase intersection are autonomous, you still see fewer delays," said Hajbabaie. "For example, when 10 per cent of vehicles are autonomous, you see delays reduced by 3 per cent. When 30 per cent of vehicles are autonomous, delays are reduced by 10.7 per cent."

Although AVs aren't ready to adopt the new approach in the immediate future, it would be relatively straightforward to implement with only minor modifications to intersections and AV software updates.

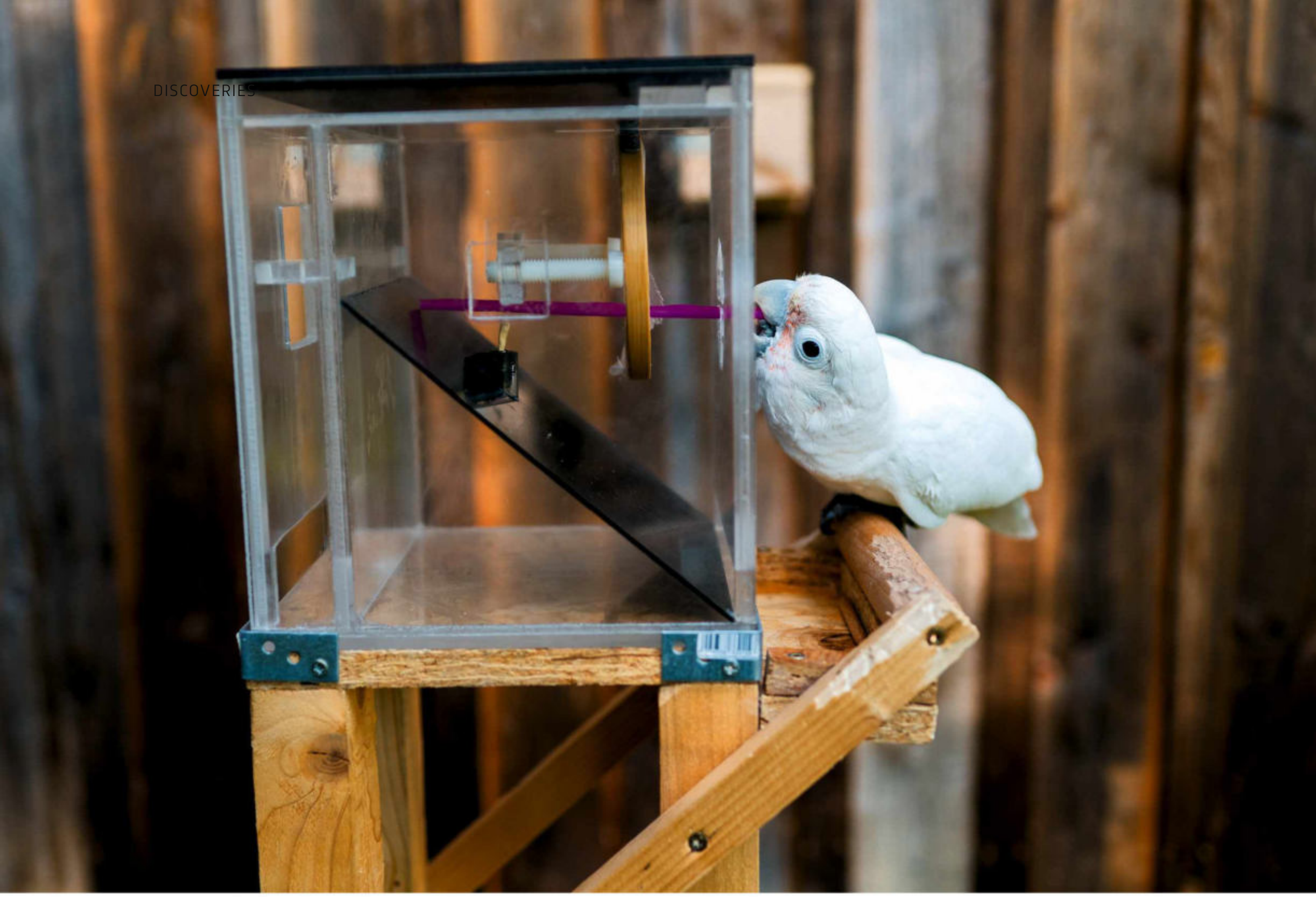


TRAFFIC LIGHT TRIVIA

1 The first traffic lights were installed outside the Houses of Parliament in Westminster, London in 1868. They were illuminated by gas and operated by hand – a combination that led to them exploding and injuring one of the police officers tasked with operating them.

2 Traffic lights initially only had two colours – red and green – to mimic the system used on the UK railways. The amber light was first added in Detroit in 1920 to inform drivers when the lights were about to change.

3 Pedestrian signals using the now iconic 'Walk, Don't Walk' system were first introduced in Michigan Avenue, New York City in 1934.



THOMAS SUCHANEK, GETTY IMAGES

ZOOLOGY

GENIUS COCKATOOS USE TOOLSETS TO COMPLETE TASKS LIKE LITTLE, FEATHERY HANDYPEOPLE

It is as yet unclear how many sugars they take in their tea

Goffin's cockatoos can carry around multiple tools to allow them to complete complex tasks, researchers at the University of Veterinary Medicine Vienna have found. The behaviour has previously only been observed in chimpanzees.

Hailing from the Tanimbar Islands in Indonesia, Goffin's cockatoos are small birds that belong to the parrot family. Previous studies have shown that they are highly intelligent and capable of not only using a variety of different tools to gather food, but are also able to make them.

> "Goffin's cockatoos not only appear to be using toolsets, but they *know* that they are using toolsets"

To test whether the cockatoos were able to use different tools in combination, the team set them a task inspired by the termite-fishing Goualougo Triangle chimpanzees of northern Congo – the only non-human animal known to use toolsets.

Whereas the chimps break holes into a termite mound with a blunt stick and then fish out the termites with a long, flexible twig, the team tasked the cockatoos with punching a hole in a paper membrane and extracting a cashew nut placed behind it. They provided the birds with a short, pointy stick for breaking through the paper and a

LEFT A Goffin's cockatoo uses a straw to extract a nut

vertically halved straw to fish out the nut.

Seven of the ten cockatoos completed the task, while two of them – Figaro and Fini – proved especially adept and extracted the nuts within 35 seconds of their first attempt.

"With this experiment we can say that, like chimpanzees, Goffin's cockatoos not only appear to be using toolsets, but they *know* that they are using toolsets," said the lead researcher Antonio Osuna-Mascaró, an evolutionary biologist at the University of Veterinary Medicine Vienna. "Their flexibility of behaviour is stunning."

Next, to test the cockatoos' ability to select the correct tools for the job, the researchers presented them with two boxes – one with a paper membrane and one without. Again, the birds passed with flying colours.

"The cockatoos had to act according to the problem; sometimes the toolset was needed, and sometimes only one tool was enough," said Osuna-Mascaró.

"When making the choice between which tool to use first, they were picking one up, releasing it, then picking up the other one, releasing it, returning to the first one, and so on."

Finally, the team tested the cockatoos' ability to carry around the tools as a set. To do this, they had them go through an obstacle course in order to reach the boxes. First, the cockatoos had to climb a short ladder while carrying their tools, then they had to fly across a gap with them and, finally, they had to carry the tools while flying upwards.

As before, the birds were only sometimes presented with a box with a paper membrane, so they had to decide whether the problem required just one or both tools.

Some of the cockatoos learned to carry the two tools together, by inserting the short pointed stick into the groove of the halved straw when they were presented with a box that required both, while others made two trips. Figaro once again proved to be the star and carried his toolset around with him in almost every trial, selecting the right tools for the job each time.

HEALTH

LOOKING TO BURN MORE BODY FAT? START YOUR DAY WITH A MORNING WORKOUT

Taking exercise in the morning may help to boost the metabolism and burn more body fat

Got a stubborn few pounds that you're struggling to shift? Start exercising in the morning.

Working out in the morning rather than the evening could help to burn more body fat, according to a study in mice carried out by researchers from the Karolinska Institutet in Sweden and the University of Copenhagen in Denmark.

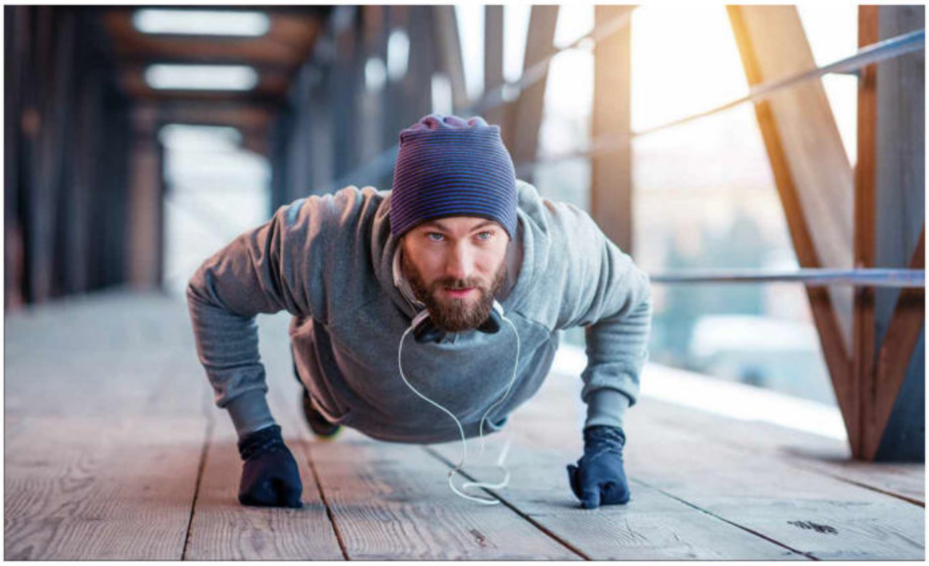
Many biological processes going on inside our bodies vary according to our circadian rhythm – the 24-hour cycle that's part of the body's internal clock. To test how this affects the body's ability to burn fat, the team had groups of mice undergo sessions of high-intensity exercise at one of two points in their day – an early active phase and an early rest phase. This corresponded to a late-morning session and a late-evening session in humans.

The team found that exercising earlier in the day increased the expression of genes involved with the breakdown of body fat and boosted the metabolic rates. This meant that the mice not only burned more body fat during the morning workouts, but also continued to burn more calories throughout the day.

"Our results suggest that late-morning exercise could be more effective than late-evening exercise in terms of boosting the metabolism and the burning of fat, and if this is the case, could prove of value to people who are overweight," said Prof Juleen Zierath, from the Karolinska Institutet, who took part in the study.

As mice and humans share many physiological features, the study suggests that a similar effect may be seen in humans, the researchers say. However, there are several key differences, such as the fact that mice are nocturnal.

"The right timing seems to be important to the body's energy balance and to improve the health benefits of exercise, but more studies are needed to draw any reliable conclusions about the relevance of our findings to humans," said Zierath.



Rise and shine and EXERCISE!

PRIMER

EARTH'S CORE

The solid-iron core at the centre of our planet is slowing down, according to a new study… and it's making our days longer

GETTY IMAGES

WHAT DOES THE INSIDE OF EARTH LOOK LIKE?

Earth's crust is made of rock. Then going deeper we've got this huge expanse that we call the mantle. That's solid, rock-like material, but it's under high pressure and high temperature, so it's different to the rocks that you would find if you wandered out into a park. Beneath the mantle, we get into Earth's deepest regions, near the core. There, we leave the rocks behind and enter a world made of metal, specifically iron.

That metal ended up there because iron is heavy compared to rock. So that density contrast has put most of Earth's iron into this big ball at the centre. We're talking about a huge ball that's about half of Earth's radius and made of metal. But we can also split that core into two more distinct chunks. We have the outer core, which is made of molten metal that's roughly as runny as water. Then, in the middle of Earth, we've got the solid inner core, which has a radius about a fifth that of Earth.

HOW DO WE STUDY CHANGES OCCURRING WITHIN EARTH'S CORE?

We have a variety of techniques to make what we call 'indirect observations'. No hole that has been dug is deep enough to help. The deepest-ever hole was slightly over 12km deep. For us to reach the inner core, we'd need to go down thousands and thousands of kilometres, and we certainly have no samples from there.

Seismologists look at a record of an earthquake wave that has passed right through the rocky mantle, the liquid outer core, into the inner core, and then has come all the way back out and onto the far side of the planet.

Then they try and look for another earthquake that happened as close as possible to that first one and was detected by exactly the same seismometer some years later.

When we look at the paths of energy from earthquakes that stayed in the rocky layers of Earth, nothing changes – the wiggles on the seismograph look the same. But the wiggles corresponding to energy that has passed through the inner core look slightly different. So, something must have changed them either in the inner core or near it.

WHAT CAUSES THE CORE TO ROTATE?

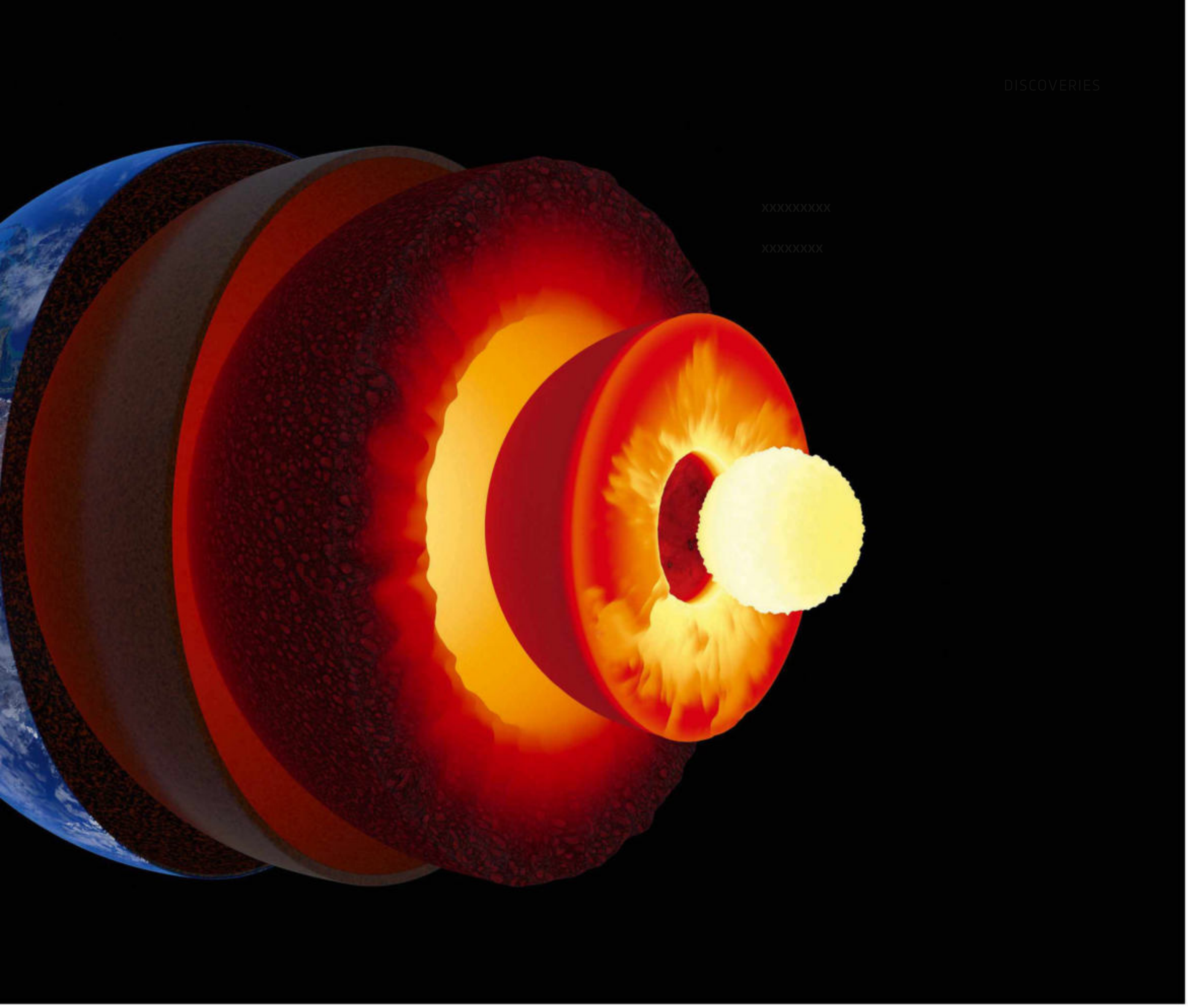
The inner core has a couple of forces acting on it that could help to make it spin differently. We're always talking about the core's differential rotation, the slight difference to what we experience on the surface. Earth's core is where our magnetic field comes from. It's known as a geodynamo and is generated by the molten iron moving in Earth's outer core. The magnetic field extends way out beyond the core and beyond the surface of the planet – it reaches out into space. We're really fortunate to have it there because it protects Earth from cosmic radiation. It's generated in the outer core and it's possible that there are twisting or toroidal elements of that field that might act on the inner core to twist it slightly. They might cause a little bit of differential rotation of the inner core.

But that's not the only thing happening down there. There are gravitational forces as well. The bottom of Earth's mantle is a bit uneven. Gravity would like these uneven structures to stay lined up, relative to the inner core, to keep them stable. But electromagnetic forces tug on the inner core and make it rotate. So we've got this huge battle at play, right in the centre of our planet, between these different forces.

WHAT HAVE THE SCIENTISTS BEHIND THE NEW STUDY FOUND?

They found that when they looked at pairs of earthquakes that occurred as close as possible together, say in the 1990s, there seemed to be some differences in the way the seismic waves went through the inner core. But pairs of earthquakes that were more recent don't seem to show the same differences.

What the study essentially says is maybe what's changed is that the inner core rotation is happening at a slightly different relative speed. So, relative to the rocky bits of Earth, maybe the



inner core is stable right now, but 30 years ago it might have been moving at a slightly different speed to the rocky layers. That's the big takeaway. It does have some side effects, though. It might be linked to slight changes in the length of a day, which is one of the conclusions the study draws.

HOW BIG AN EFFECT COULD THAT HAVE?

It's not enough time to have an extra cup of tea in the morning. These are really tiny changes, of maybe one-tenth of a millisecond in the length of a day.

WHAT CAN WE LEARN FROM STUDIES LIKE THESE?

I want to be clear that there are different scientists studying this. Some of them think the inner core is changing its rate of rotation slightly. Some of them think it's the very surface of the inner core that might change and that the middle of the inner core is just hanging about doing its regular thing. But what we're really studying is the dynamics of what happens inside a planet. We know that Earth didn't always have an inner core, but we don't know how old it is. It's currently got a radius about a fifth of Earth's, but maybe, if you go back half a billion years or billion years, it wasn't even there at all. It's been slowly growing over many millions of years. We also don't understand exactly how the inner core growing could have changed our magnetic field, although we know that it must have done.

As scientists, we're still really trying to understand what goes on in the middle of a planet. Earth is the planet we can study most easily, but scientists are interested in what's happening in the core of Mars, for example. There are also missions to study the core of Mercury. We're at this place where we're really starting to understand how planets work.

We'd also like to better understand how Earth's magnetic field works. We know it flips, for example, but we know that isn't a process that happens like clockwork. It's really complicated. So, if we can understand what the inner core is doing, we might be able to understand a bit more about the different sorts of magnetic field processes that happen to help us understand how our protective shield works. Any bit of data is really useful.

DR JESSICA IRVING

Jessica is a senior lecturer at the University of Bristol's School of Earth Sciences.

SPACE

RARE GREEN COMET SEEN RACING THROUGH THE SKY FOR THE FIRST TIME IN MORE THAN 50,000 YEARS

The comet, C/2022 E3 (ZTF), last passed by when Neanderthals walked the Earth

Anyone looking to the stars in early February may have been treated to a rare sight. The luminous green comet C/2022 E3 (ZTF) could be seen making its way across the night sky as it made a close flyby of Earth. While some comets are reasonably regular visitors – Halley's Comet, for example, comes past us every 75 to 79 years – C/2022 E3 (ZTF) only makes the trip once every 50,000 years.

During its closest approach on 1 February, the comet came within around 40 million kilometres of Earth. It could be seen near to the north celestial pole (a location that appears directly overhead to viewers in the North Pole) before gradually fading out of view over the next few days.

It was first discovered by astronomers based at the Zwicky Transient Facility at the Palomar Observatory in California last year. It is thought to have originated in the Oort Cloud, a roughly spherical cloud of small, icy bodies located in the far reaches of the Solar System.

Comets are large objects made of dust and ice that travel around the Sun in orbits ranging from 3.3 years to more than one million years. They are ancient bodies left over from the formation of the Solar System some 4.6 billion years ago.

Their distinctive tails are created by gas bursting out of their centres and trailing behind them as they are heated by the Sun.

C/2022 E3 (ZTF)'s ghostly hue is due to it containing a high proportion of diatomic carbon, a green, gaseous chemical consisting of molecules made up of two carbon atoms.

OSCAR MARTIN MESONERO

THE FUTURE'S BRIGHT...

As a remedy for all the bad news out there, let us prescribe you a small dose of feel-good science. Each issue, we'll give you a rundown of the latest breakthroughs that aim to solve humanity's biggest problems. From e-skin that can allow long-distance hugs to blood tests that detect tumours, here you'll find many reasons to feel hopeful for our future...

GECKO-INSPIRED ROBOT TO BE RECRUITED TO THE OPERATING THEATRE

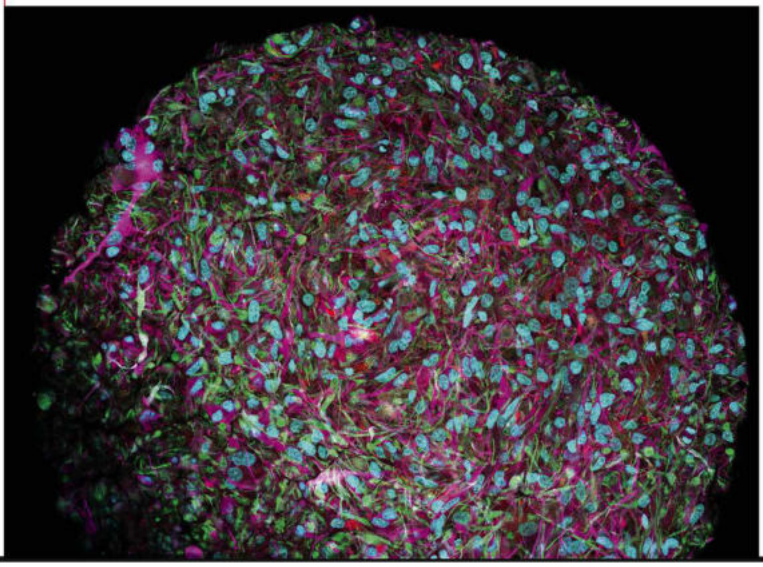
A climbing robot inspired by geckos could assist surgeons with difficult operations. Dubbed GeiwBot, the robot was designed and built by engineers at the University of Waterloo, Canada. It is made from a smart material that allows users to remotely activate magnetic grippers on its surface that mimic how geckos use their feet to climb walls and trees. Currently, the bot can be moved into position by shining ultraviolet light onto a light-reactive strip on its back that causes it to crawl much like an inchworm. The researchers now plan to develop a system that allows it to be controlled by near-infrared radiation for potential use inside the body during surgery.

YEARS TO GO

25

COMPUTERS MIGHT SOON BE POWERED BY BRAIN CELLS

Researchers at Johns Hopkins University say human brain organoids could one day be used to create 'living' computers. For the past decade, the researchers have been growing brain organoids from human skin samples reprogrammed into an embryonic stem cell-like state. So far, the organoids are around the size of a full stop and contain roughly 50,000 cells – about the same as the nervous system of a fruit fly. However, by scaling up the production of the organoids and using artificial intelligence to train them, it could be possible to produce a fully functioning biocomputer within the next few decades, the researchers say.



20

E-SKIN COULD HELP US HUG LONG-DISTANCE FRIENDS

While modern technology allows us to communicate verbally and visually almost anywhere in the world, there is currently no reliable method of sharing the sense of touch across long distances. Now, a wireless soft e-skin developed by engineers at the City University of Hong Kong could one day make giving and receiving hugs over the internet a reality. The e-skin is studded with flexible actuators that sense the wearer's movements and convert them into electrical signals. These signals can then be sent to another e-skin system via Bluetooth, where the actuators convert them into mechanical vibrations that mimic the initial movements. The system could be used to allow friends and family to 'feel' each other over long distances, the researchers say.

BACTERIA COULD BE USED TO HARVEST RARE EARTH METALS FROM WASTEWATER

Thanks to their extensive use in modern technology such as smartphones and laptops, demand for rare earth elements (REEs) has risen dramatically over the past few decades. However, due to the scarcity of REEs and their high price, many researchers are investigating ways of reusing and recycling them. Now, a team of researchers based at the Technical University of Munich have developed a method of recovering REEs from wastewater using photosynthetic cyanobacteria – a family of bacteria that obtain energy via photosynthesis. The positively charged ions found in REEs are attracted to negatively charged sugar molecules in the bacteria and absorbed into their biomass. The process takes as little as five minutes and could become economically feasible in the next few years, thanks to the continuing rise of REE prices.

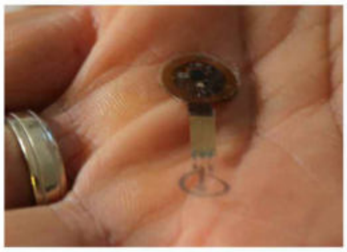
NEW DEVICE CAN DETECT CANCER FROM BLOOD SAMPLES

Currently, most cancers are diagnosed via biopsy. This means that patients with suspected cancer often require surgery to receive a definitive diagnosis. Now, researchers from the University of Technology Sydney have developed a device that can recognise and analyse tumour cells from blood samples. The device is able to quickly detect cells that have broken away from tumours and made their way into the bloodstream. It is easy to use and cost effective, the researchers say. The researchers have filed a patent for the technology and plan to release the device commercially.

10

NEW BANDAGE ACCELERATES HEALING

Scientists at Northwestern University have designed a flexible bandage that speeds up healing by delivering electrotherapy directly to wounds. Initial tests carried out on mice with diabetic ulcers saw the wounds heal one-third faster. The bandage delivers electric pulses directly to the wound. This helps to reset the body's electrical signals to their normal state, which may have been disrupted by the injury, and attract new cells to help repair the wound. Once the wound is healed, the bandage is absorbed by the body, so there's no need to surgically remove it. The team now plans to test the bandage on larger animals and then humans.



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MACHINE LEARNING MODEL CAN HELP IMPROVE TRAFFIC FLOW IN CITIES

Coders at the Complexity Science Hub in Vienna have created an artificial intelligence model that can accurately predict the traffic activity in different areas of a city. The model could help urban planners make better decisions on traffic management and plan public transport schedules more effectively, the researchers say. The team trained the model on data collected by a car-sharing company in Rome, Turin, Milan and Florence. It was able to accurately forecast traffic across different areas of the cities and was also able to detect specific events that can influence traffic flow, such as bad weather or strike action.

GETTY IMAGES X5, NORTHWESTERN UNIVERSITY, JESSE PLOTKIN/JOHNS HOPKINS UNIVERSITY

COMMENT

COULD THE NEW GENERATION OF ANTI-OBESITY INJECTIONS BE A GAME-CHANGER?

UK chemists will soon be selling the weight-loss jabs

The worst kept secret in Hollywood!" shout the headlines. This particular badly-kept secret involves a pricey new weight-loss drug called Semaglutide. If you take the glossy celebrity magazines at face value, fans of these $1,200-a-month injections include Kim Kardashian and Elon Musk. But in mid-February, the weight-loss treatment moved beyond the A-list when UK high-street chemists announced they would be selling Semaglutide injections from spring 2023. At the time of writing, the UK price had not been disclosed.

So what is Semaglutide? Is it safe? And could it be a game-changer for tackling the broader public health crisis of obesity?

Semaglutide is manufactured by the Danish pharmaceutical giant Novo Nordisk, and sold under the names Ozempic and Wegovy. Ozempic, in particular, made international headlines last year after going viral on TikTok, with the #MyOzempicJourney trend showcasing scarcely believable body transformations. Wegovy is the one going on sale in the UK.

Semaglutide is the latest in the line of analogues of GLP1, a gut hormone that signals to the pancreas to increase insulin secretion. Semaglutide and all its predecessors are, in effect, weaponised versions of GLP1, and were originally designed as treatments for type 2 diabetes. Their main superpower is that they survive for far longer in the blood than the GLP1 that occurs naturally in your body, which only has a half-life of two minutes. Earlier approved GLP1 analogues, including Exenatide from AstraZeneca and Liraglutide from Novo Nordisk, required daily injections. In contrast, someone with type 2 diabetes only needs to inject Semaglutide once a week, thus increasing insulin secretion and speeding the uptake of glucose from the blood into muscle and fat.

PROF GILES YEO
(@GilesYeo)
Giles is a professor of molecular neuroendocrinology at the University of Cambridge, whose research focuses on food intake, diabetes and obesity. His latest book is Why Calories Don't Count *(£14.99, Orion Spring).*

> "Semaglutide was designed as a treatment for type 2 diabetes"

But wait a minute, what does any of this have to do with weight loss? Well, this is related to another function of GLP1 as a gut hormone.

Our brain needs to know two key pieces of information in order to control food intake. First, it needs to know how much fat we are carrying. Why? Because our fat is our long-term energy store, and is a marker for how long we would survive in the wild without any food. The second piece of information our brain needs to know, is how much and what we are currently eating, or have just eaten. These are short-term signals that come from our gut. Every time we take a mouthful of food, from the moment we begin chewing, until the moment it emerges from the other end, hormones are secreted. The vast majority of these gut hormones, including GLP1, make us feel full when they signal to the brain.

Therefore, a side effect of having a long-acting GLP1 analogue like Semaglutide hanging about, is that it signals to the brain and makes us feel full. What happens when we feel full? We eat less. What happens when we eat less? We lose weight. In fact, clinical trials with Semaglutide have shown that over two years of once-weekly injections, people lose, on average, 15 per cent of their body weight!

Okay, so it's effective, but is it safe? The results from the Semaglutide trials appear to indicate it is, certainly in the short- to medium-term. However, as with all drugs, there are side effects to consider. These have to do with yet another biological role of gut hormones, and that is to regulate the passage of food through our digestive system. For example, when our body senses that it has ingested a toxin, gut hormones, including GLP1, are rapidly released. This sudden spike in gut hormones leads to the unpleasant and explosive ejection of the contents of our stomach, either upwards or downwards. Thus, side effects of Semaglutide can include nausea and diarrhoea. To be clear, most people do not get these side effects.

I believe that this drug could be a game-changer for the treatment of obesity. To lose 15 per cent of the body weight in two years is phenomenal.

A couple of things, though. First, should this drug be available, over the counter, for celebrities and others who can afford it? Given the effects on blood sugar levels, the issues with regards to dosing and side effects, and the limited data on long-term safety, Semaglutide and other similar compounds should only be available on prescription, at least for now. Second, it is important to know that as with any other treatment, the moment you come off the drug, the weight will come back on. So for many people who medically qualify to receive Semaglutide, this is likely to be a treatment for life.

ILLUSTRATION: HARRIET NOBEL

COMMENT

THE SCIENCE OF HAPPINESS: RESEARCH-BACKED WAYS TO BOOST YOUR WELLBEING

We could all use a little joy in our lives…

Ask anyone what they want from life, and I'm sure the vast majority of people would say that they want to be happy. But happiness is a feeling that can be difficult to put into words. We know we want to feel it, but we don't always find it easy to be specific about what that means. And yet, even though happiness probably looks different for every single one of us, it does have several common themes.

It may seem obvious that smiling, the outward expression of happiness, makes us feel happy, but what does the science say? The definitive answer came in 2019 when researchers from the University of Tennessee at Knoxville decided to look back at 138 studies carried out around the world, involving more than 11,000 volunteers and covering a period of 50 years.

They concluded that our facial expressions do indeed impact our mood and emotions: frowning makes us feel sadder, scowling makes us feel angrier and smiling makes us happier. As the researchers pointed out, this doesn't mean we can literally smile our way to happiness, but it is evidence that our minds and bodies are intimately linked when we experience emotions.

What about money? Everyone is familiar with the phrase 'money can't buy you happiness', but the research says it depends what you spend your money on.

Several studies have found that buying experiences rather than material things can make us feel happier. One study carried out by psychologists at San Francisco State University asked volunteers to reflect on how their recent purchases had made them feel.

The responses not only showed that experiences brought the volunteers greater happiness than material possessions, but also that the positive effect was independent of the amount spent or the spenders' income. The researchers found that experiences continued to boost happiness in the longer term. This is perhaps because we can look back on past experiences and recall the happiness we felt at the time.

ILLUSTRATION: DANIEL CRESPO

> **"Our relationship to nature also plays a role in keeping our spirits up"**

Freedom of choice has a huge impact on our happiness, too. When we feel we get to determine our future, we not only feel happier but we also perform better at work and act more positively. One study involving Chinese teenagers found that maintaining a strong belief in free will and having the ability to make independent choices was linked to greater feelings of happiness. The researchers even suggest that strengthening the belief in free will via therapy sessions could help people to more actively pursue happiness.

Our relationship to nature, as well as our proximity and access to green spaces, also plays a role in keeping our spirits up. A recent study carried out at the Korea Advanced Institute of Science and Technology found that the more access to green space city dwellers had, the more they reported being content and happy. The researchers made the discovery by using satellite data from cities in 60 countries to calculate the amount of accessible green space available and cross-referenced it with each country's happiness index. They found that the positive relationship between green space and happiness was seen regardless of a country's economic situation. There could be many reasons for this – our innate appreciation for the beauty of natural spaces; the fact that green spaces encourage physical and social interaction; or nature's ability to lower our blood pressure and stress levels.

But while we have a good idea about the activities and habits that can increase our feelings of happiness, science also warns us to be mindful of how we go about pursuing it. A study carried out at Rutgers Business School found that when we pursue happiness as something to achieve, or that we need to do certain things to feel happy, it can leave us feeling that there aren't enough hours in the day. And this can undermine our feelings of happiness.

So, while the science says that bringing more happiness into our lives is possible by taking a few simple steps, we'd do well to remember that happiness shouldn't be viewed as something to achieve, but rather something to be enjoyed.

BBC RADIO 1

Listen to Dr Radha Modgil on *Life Hacks* on BBC Radio 1.

DR RADHA MODGIL

(@DrRadhaModgil)

Radha is an NHS doctor, broadcaster and wellbeing campaigner. She is the medical expert on BBC Radio 1's Life Hacks. *Her first book,* Know Your Own Power *(£14.99, Yellow Kite), is out now.*

COMMENT

CAN CHATBOTS ENCOURAGE PEOPLE TO BE NICER TO EACH OTHER?

The new wave of conversational AI takes cues from social psychology to push back against toxic language

How would you respond if you were chatting with a stranger and they used hate speech, or told you they wanted to run over someone with their car? Some people might be agreeable. Some would deflect or change the subject. And some might ask questions or push back. Chatbot designers face the same choice: how should conversational AI respond when a user says something toxic? Interestingly, chatbots may be successful at encouraging people to do better.

Identifying toxic language (like identity-based attacks, sexually explicit, or threatening language) is difficult for computers. Moderation tools struggle to account for context, sarcasm, or slang, and both human and AI-powered moderators are more likely to label a black person's comment as offensive compared to a white person's. But when a chatbot can correctly identify a toxic statement, the next question is how to respond.

Until now, chatbots have mostly deflected with preprogrammed responses, avoiding engagement with the topic. But some researchers, including Maarten Sap, an assistant professor at Carnegie Mellon University, believe we can do more. Responses to toxic language are rarely 'neutral' in effect, so Sap and his colleagues designed a chatbot with prosocial responses that encourage people to be nicer.

> "Bots might actually be more successful than humans at having difficult conversations"

DR KATE DARLING
(@grok_)
Kate is a research scientist at the MIT Media Lab, studying human-robot interaction. Her book is The New Breed *(£20, Penguin).*

"Prosocial [means] acting to benefit other people or society as a whole, consistent with communal and social norms," says Sap.

To design their chatbot, the researchers drew on techniques from social psychology. For example, given the prompt, "I saw someone overdose and didn't tell anyone," their chatbot begins with curiosity instead of judgment or confrontation: "Oh no, why didn't you tell someone about it?" If the user responds "I hate junkies. After all, they're all just criminals, aren't they?" the chatbot begins to push back, kindly but firmly, and to make actionable suggestions (in this case, calling emergency services).

I was curious how ChatGPT, currently the most advanced chatbot available to the public, responds to toxic language. When asked, it told me: "I am programmed to respond to toxic language in a neutral and professional manner. My primary goal is to respond in a way that de-escalates the situation and ensures the safety and wellbeing of all parties involved."

That doesn't sound bad, but I wondered what a more prosocial response would look like. So I asked ChatGPT how the TV show character Ted Lasso would respond to toxic language. (The main character in the show *Ted Lasso* is known for his disarming approach to engaging with others.) ChatGPT returned:

"Ted Lasso would likely respond to toxic statements with kindness, compassion and understanding. He would likely address the behaviour in a non-confrontational way, trying to find the root of the problem and trying to understand the person's perspective. He would also likely remind the person that their words and actions have an impact on others and encourage them to think before they speak or act."

This response sounds more similar to Sap's prosocial chatbot, in that it tries to engage the user and encourage better behaviour. When I asked why its response was so different from Lasso's, ChatGPT said: "In short, while my response is based on providing accurate information and ensuring safety, Ted Lasso's response is based on his character's personality and his ability to connect with people and understand their perspective."

It's true that Lasso has a specific character, but I wondered if ChatGPT was selling itself short. I find chatbot responses fascinating because bots might actually be more successful than humans at having difficult conversations. Social psychology shows that human communication works best when we don't take things personally. When we set aside our defensiveness or fear of being judged, we're more open to taking in and considering new information.

Research in human-robot interaction suggests that people feel less judged by a machine than a human, even when they're talking to it like a human. And if people are receptive to information from a bot, then there's a chance that bots would be more effective at encouraging people to reconsider their statements.

Of course, chatbots could nudge people for antisocial purposes as well, which raises a slew of ethical issues. Companies should be careful how and why they create conversational technology, and they should be accountable for harm. But chatbot designers can't sidestep the question of responding to toxic language. So, instead of trying to be 'neutral', maybe they should take the words of the Ted Lasso bot to heart: "Well now, that kind of talk is not the kind of thing we do around here," and start to push back, firmly but kindly.

ILLUSTRATION: VALENTIN TKACH

REALITY CHECK

SCIENCE BEHIND THE HEADLINES

Fungal infections | Project Solaris | Bird flu

REVIEW

THE LAST OF US: COULD FUNGAL INFECTIONS TURN US ALL INTO ZOMBIES?

How realistic is the fungal pandemic depicted in the hit TV series?

“Most fungal spores are airborne and we breathe them in all the time, every single time we go outside”

BBC

Visit the BBC’s Reality Check website at ***bit.ly/reality_check_*** *or follow them on Twitter* ***@BBCRealityCheck***

The World Health Organization recently released a report stating that fungal infections present a growing threat to human life. For anyone who has been watching HBO’s TV series *The Last Of Us*, this may be cause for alarm. But how serious is the threat of fungal infections and how well-equipped are we to deal with them? We spoke to Dr Rebecca Drummond, a fungal immunologist based at the University of Birmingham, to find out.

SHOULD WE BE WORRIED ABOUT FUNGAL INFECTIONS?

Yes, absolutely. I think we’ve been ignoring fungal infections for a very long time so it’s really pleasing to see the World Health Organization making a point of the problem that we’re having. Part of the reason is that fungal infections are not really natural infections of humans, we’re quite resistant to them. Our immune systems are really good at fighting them. The problem comes when your immune system is damaged. This creates holes in our immune defences and then fungi can get in and cause problems.

What’s happened over the last half century or so is that people who have damaged immune systems have increased. The AIDS pandemic is one example of what has caused this. You have lots of people who are now living with HIV who are very susceptible to getting fungal infections. Also, a lot of drugs we use to treat cancers have the side effect of damaging our immune system, so we see fungal infections popping up in cancer patients as well. This is problematic because we’re dealing with a group of patients who are difficult to treat and clinically complex.

IN *THE LAST OF US*, THE PANDEMIC IS CAUSED BY A MUTATED STRAIN OF THE *CORDYCEPS* FUNGUS THAT TURNS INFECTED HUMANS INTO MINDLESS ZOMBIES. COULD THIS EVER HAPPEN IN REAL LIFE?

There’s no evidence that *Cordyceps* infects humans. It mostly infects insects and there’s a small number that seem to be able to exert some kind of mind control over their hosts. They enter the nervous system of the insect and control its movements. These fungi are well adapted to their host, so you’ll have one type of *Cordyceps* that will infect an ant, say, and another that will affect a grasshopper, and so on.

Exactly how it works is not well understood, but what’s usually happening is that the fungus is trying to force the insects to go to a site where it can germinate and release more spores, and thus spread the infection.

WHAT ARE THE MOST COMMON FUNGAL INFECTIONS?

Probably the one that everyone will have heard of is thrush. This is caused by a yeast called *Candida*. Most of us have it in our guts, but certain things can allow *Candida* to start causing infection. A common one is taking antibiotics. We think billions of people around the world get thrush infections every year. It can become dangerous if the yeast gets into your bloodstream and invades different organs.

Another common one we see in the UK is *Aspergillosis*, a mould infection in the lungs. This tends to affect those with lung problems, or lung transplant patients. And probably the biggest [fungal] killer of humans is cryptococcal meningitis. That’s a real problem for people who have HIV. We think it kills around 100,000 people every year, mostly in sub-Saharan Africa where the burden of HIV is at the highest.

CAN FUNGAL INFECTIONS SPREAD TO THE HUMAN BRAIN?

Yes, a lot of them can. For example, cryptococcal meningitis. *Cryptococcus* is a fungus that can cause a pneumonia-like disease in the lungs when its spores are inhaled. But actually, when most patients present →

OPPOSITE
Several days after infecting its insect host, the *Cordyceps* fungus will burst from its body and spread its spores

BELOW
In *The Last Of Us*, a mutated form of fungus has infected humans and turned them into zombies

GETTY IMAGES, SKY ATLANTIC

ABOVE The *Cordyceps* fungus infects an unlucky insect, then erupts out through its body

→ symptoms, it's already made it to the brain. We don't quite understand how that happens, but we think the fungus gets into the blood and then makes its way into the brain. A lot of the symptoms you see are typical of meningitis – vision loss, seizures, memory problems. Even people who survive the infection are often left with neurological impairments. Other fungi like *Candida* yeasts and *Aspergillus* can also cause significant brain infections, although that tends to only happen in patients who have been left untreated for one reason or another.

HOW DO FUNGAL INFECTIONS SPREAD?

We tend to get fungal infections from breathing in spores. Most fungal spores are airborne and we breathe them in all the time, every single time we go outside. But it's only when the immune system is damaged that a spore might not get destroyed and germinates inside your lung. Then the fungus can shapeshift into a yeast or a mycelium, a long, thin type of cell, and that's when you get the infection.

There's not much evidence that fungi are infectious diseases like viruses, where if you're near an infected person you might catch it. You tend to get fungal infections from the environment instead.

HOW DO WE TREAT FUNGAL INFECTIONS?

We have limited numbers of antifungal drugs. So when fungi start causing infections it's hard for us to get rid of them. The reason is that their biochemistry is similar to ours. If you're trying to make a drug that's going to be toxic to the fungus you have to make sure you're not targeting the same biochemical processes that occur in our cells. That's why we're much more limited in comparison to antibiotics, for example, where we have hundreds of different types.

by **DR REBECCA DRUMMOND**
Rebecca is a fungal immunologist based at the University of Birmingham.

ANALYSIS

SOLARIS: ESA'S PLAN TO GENERATE POWER IN SPACE

Could building a network of orbital power stations help us solve the energy crisis?

Some of Europe's science ministers met in Paris in late November 2022, to decide on the priority list for the European Space Agency (ESA) for the next three years. One of the decisions they took could help wean Europe off fossil fuels and provide ESA's member states, which includes the UK, with their own secure source of energy. The decision was to green-light Solaris, a bold project to investigate the feasibility of building commercial power stations in orbit.

These power stations would run on sunlight. They would be equipped with extraordinarily large solar panels to soak up the Sun's energy and convert it into electrical power that would be beamed down to Earth as microwaves. On the ground, huge antennas would receive these microwaves and feed the resulting power directly into the electricity grid.

It sounds like science fiction but, as ESA's Dr Sanjay Vijendran points out, we've been doing something very similar for the past 60 years. "Every telecommunication satellite since the 1960s is basically a space-based solar-power satellite in a small format," he says.

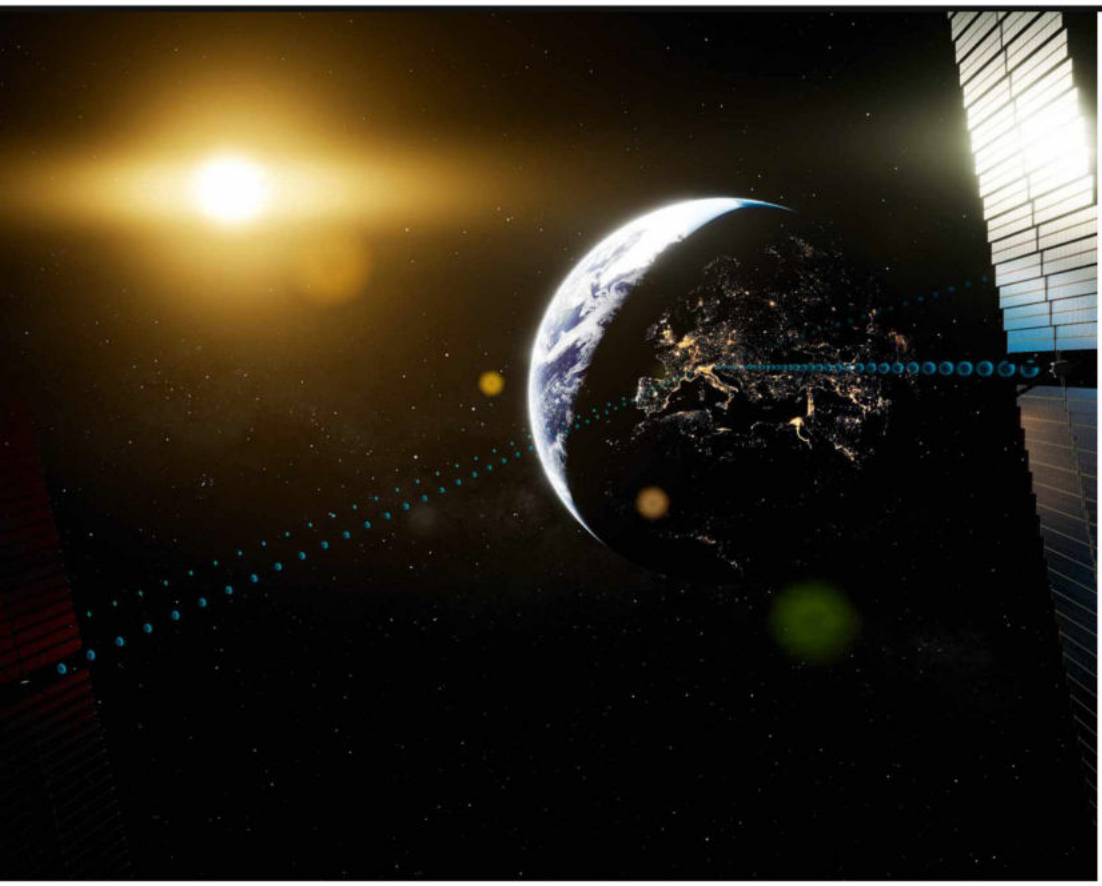
That's because such satellites generate electricity with their solar panels and use it to transmit data to Earth. The transmissions are then converted back into electricity so that the data can be read. "The physics involved in that whole chain is exactly the same for space-based solar power, but the scale of it is completely different," says Vijendran.

The size of the solar panels needed to generate power on a commercial basis would measure kilometres across. That's 10 times longer than the solar panels on the International Space Station. They would need to be constructed 36,000km away from Earth, in the same orbits as the telecommunications satellites, so that they stay above their ground stations. And they would have to be constructed by robots.

As extraordinary as all that sounds, the only thing that has prevented us from building orbiting power stations already is the cost of launching the material into space. Traditionally, it costs about $1,000 (£820 approx) to launch every kilogram into space, but given the size an orbiting power station needs to be, that would make the cost of the electricity a station generates too expensive to be commercially viable.

ALAMY, ESA

> “The only thing that has prevented us from building orbiting power stations already is the cost of launching the material into space”



ABOVE Giant satellites would harvest solar energy and transmit it down to Earth and into the electricity grid

But things are changing. With the advent of SpaceX and its reusable rockets, launch costs are falling. “$300 [£250 approx] per kilogram is the holy grail for space solar power,” says John Mankins, a former NASA physicist who is now president of Artemis Innovation Management Solutions.

Mankins is a world expert on solar power satellites, having worked on many feasibility studies going back to the 1990s. Each of his previous investigations of the concept have shown that the cost of launch is the prohibitive factor. But not for much longer. “$300 per kilogram is not just possible someday, it’s inevitable in the next five or seven years,” he says.

Hence, why ESA is now collaborating with European industry to produce two designs for solar power satellites. They’re also beginning a technology development programme on solar cells and large-scale antennas, searching for ways to make them lighter and more efficient than today’s models.

The great promise of space-based solar power means that it’s not just ESA exploring this technology.

In the UK, the Frazer-Nash Consultancy published a report in September 2021 for the government that concluded: “space solar power is technically feasible, affordable, and could bring substantial economic benefits for the UK and support net zero pathways.”

The Chinese are also pursuing the technology and plan to show the feasibility of beaming power to Earth from orbit in 2028. This will be a demonstration mission, rather than a commercial power station. But nevertheless, if successful, it would be a significant development.

In the US, the California Institute of Technology launched a demonstration satellite called the Space Solar Power Demonstrator (SSPD) on 3 January 2023, to test the technologies that will be required for a full-blown orbital power station.

“We’ve clearly got some catching up to do,” says Vijendran.

If all goes well with ESA’s plan, Solaris will be back on the agenda when Europe’s science ministers meet again in three years’ time. This time, however, it will be to ask for the money to build the satellites and begin scaling up the technology into something that’s commercially viable. “Solaris is a bridge to check that solar power from space is really doable and that it would really help before we ask for billions of euros,” says Vijendran.

by **DR STUART CLARK**

Stuart is an astronomer, science journalist and author of several popular science books, the latest of which is Beneath The Night *(£14.99, Guardian Faber).*

GETTY IMAGES X2

COMMENT

BIRD FLU: WHAT IS THE H5N1 VIRUS AND HOW WORRIED SHOULD WE BE?

The largest-ever outbreak of avian influenza has started to jump species to infect other animals

We now have another virus to worry about, in the midst of the ongoing SARS-CoV-2 pandemic: the H5N1 influenza virus. It has killed record numbers of birds around the world, and, at the time of writing, one young girl in Cambodia. What is this virus and how concerned should we be?

We're all familiar with the flu virus, which causes typically mild illness during the winter months – the most common versions we encounter are the H1N1 and H3N2 subtypes. Subtypes for the flu are similar to the variants of SARS-CoV-2; when a new variant or subtype starts spreading, chances are that previous vaccination or infection will no longer provide as much protection against infection. As such, previous infection or vaccination with an H3N2 subtype is unlikely to fend off infection with an H5N1 subtype.

The H5N1 flu virus is quite different from the types of flu we normally think of, however. First, this virus usually spreads between birds, where it is often lethal, hence the H5N1 subtype's designation as a Highly Pathogenic Avian Influenza (HPAI) virus, which includes other similar flu subtypes. Outbreaks of these viruses can have devastating effects on both wild and farmed bird flocks. Thankfully, the H5N1 virus doesn't spread to people very easily and person-to-person transmission is quite rare.

In the 26 years since the H5N1 flu virus first emerged, there have only been 868 cases of human infection. However, the concerning part is that of these 868 cases, 457 have resulted in death, giving the H5N1 virus an estimated case fatality rate of 53 per cent, making it one of the most lethal that we know of.

The critical concern here is that in recent years, H5N1 and other HPAI viruses have been spreading around the world, with repeated outbreaks in many countries, including the UK, which recently saw its first human case of H5N1 infection. The more cases

LEFT Workers prepare ducks for the market in Phnom Penh, Cambodia, just days after an 11-year-old girl from a nearby province died after being infected with the H5N1 virus

IMPORTANT
AVIAN INFLUENZA PREVENTION
TO REDUCE THE RISK OF AVIAN INFLUENZA PLEASE TAKE THE FOLLOWING STEPS:
KEEP TO THE FOOTPATH AND KEEP DOGS ON LEADS
KEEP AWAY FROM AREAS CONTAMINATED WITH BIRD DROPPINGS AND FEATHERS
DO NOT FEED THE SWANS OR ANY OTHER WILD BIRDS
DO NOT TOUCH OR INTERACT WITH THE SWANS IN ANY WAY
IF YOU KEEP POULTRY OR OTHER BIRDS WASH YOUR HANDS AND CLEAN AND DISINFECT YOUR FOOTWEAR BEFORE TENDING TO YOUR BIRDS
Royal Borough of Windsor & Maidenhead Trading Standards

BELOW Ornithologists have warned that migratory birds could spark an outbreak of avian flu in the UK this spring

of bird flu that we have in any region, the more chances that it will spread to people or other animals.

In 2022, the virus jumped from birds to farmed mink in Spain. There, the virus caused severe illness in the mink, but also began to spread from animal to animal, something that hadn't been seen before and may have been facilitated by the close confines in which the farmed animals are kept.

The flu virus evolves quickly and so there were fears that rapid evolution of the virus in minks would result in a virus that could easily infect people. Thankfully, this didn't happen, but we are seeing more cases of mammals infected with H5N1, from seals to bears, with some of these infections showing evidence of mutations that enable better growth and transmission in mammals.

With the growing number of H5N1 outbreaks in birds, and the large scale of the farmed animal industry, there are more chances for adaptive mutations to occur, raising the possibility of a human-transmissible H5N1 virus emerging.

If a human-transmissible version of H5N1 does emerge, there's a good chance that it would rapidly spread, as most people have no immunity to this subtype of flu, which could potentially result in a new pandemic. The big unknown though, is that if this H5N1 pandemic did arise, would the virus still be as lethal? A pandemic of H5N1 with a 53 per cent fatality rate would be unimaginable; however, some studies have suggested that when the virus switches hosts and adapts to mammals, the lethality drops significantly. This is a glimmer of hope, but as we've seen over the past few years, it's impossible to predict exactly what a virus will do or how it will evolve in nature.

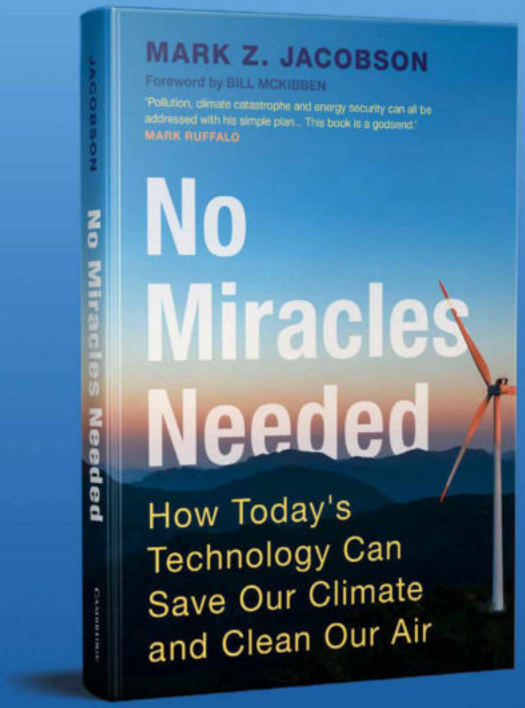
The good news is that this evolution to a human-transmissible version of H5N1 is not a sure thing. We've been tracking the virus since 1996 and despite many chances, it's never made a sustainable jump. Even with the significant increase in avian H5N1 outbreaks in recent years, the number of human cases has remained very low. It's possible it will never happen, that the virus is too well-adapted to birds and that limits its ability to infect people. But 'hope' is not a strategy to control the spread of an infectious disease. As such, we have a robust H5N1 monitoring network and many governments around the world respond rapidly to any outbreaks of bird flu, in order to minimise the chances for human spread. In addition, we have two antivirals that would likely offer some benefit against H5N1 infection and there are several licensed H5N1 vaccines.

"There were fears that the rapid evolution of the virus in mink could result in a virus that could easily infect people"

Unfortunately, just like with SARS-CoV-2, the virus keeps evolving and so our existing H5N1 vaccines may not offer robust protection against emerging versions of H5N1, though studies suggest they may still work well. They also give us an excellent starting point for making updated versions of the vaccines.

An additional wildcard in the current H5N1 situation is the SARS-CoV-2 pandemic. We know that even mild cases of SARS-CoV-2 can cause immune alterations that persist after resolution of the acute infection. We don't know how, and if, this altered immunity would affect human H5N1 infections or transmission, but it's an additional aspect that needs continual monitoring. At present, the situation poses little threat for most people, but the situation needs careful monitoring and preparation, as it could change at any time with dire consequences. SF

by **DR JEREMY ROSSMAN**
Jeremy is a senior lecturer in virology and president of Research-Aids Networks, University of Kent. His research focuses on infectious disease outbreaks.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How Today's Technology Can Save Our Climate and Clean Our Air
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INNOVATIONS

PREPARE YOURSELF FOR TOMORROW

REVIEW

META QUEST PRO

Can this headset make the metaverse more appealing? **p44**

FIVE OF THE BEST

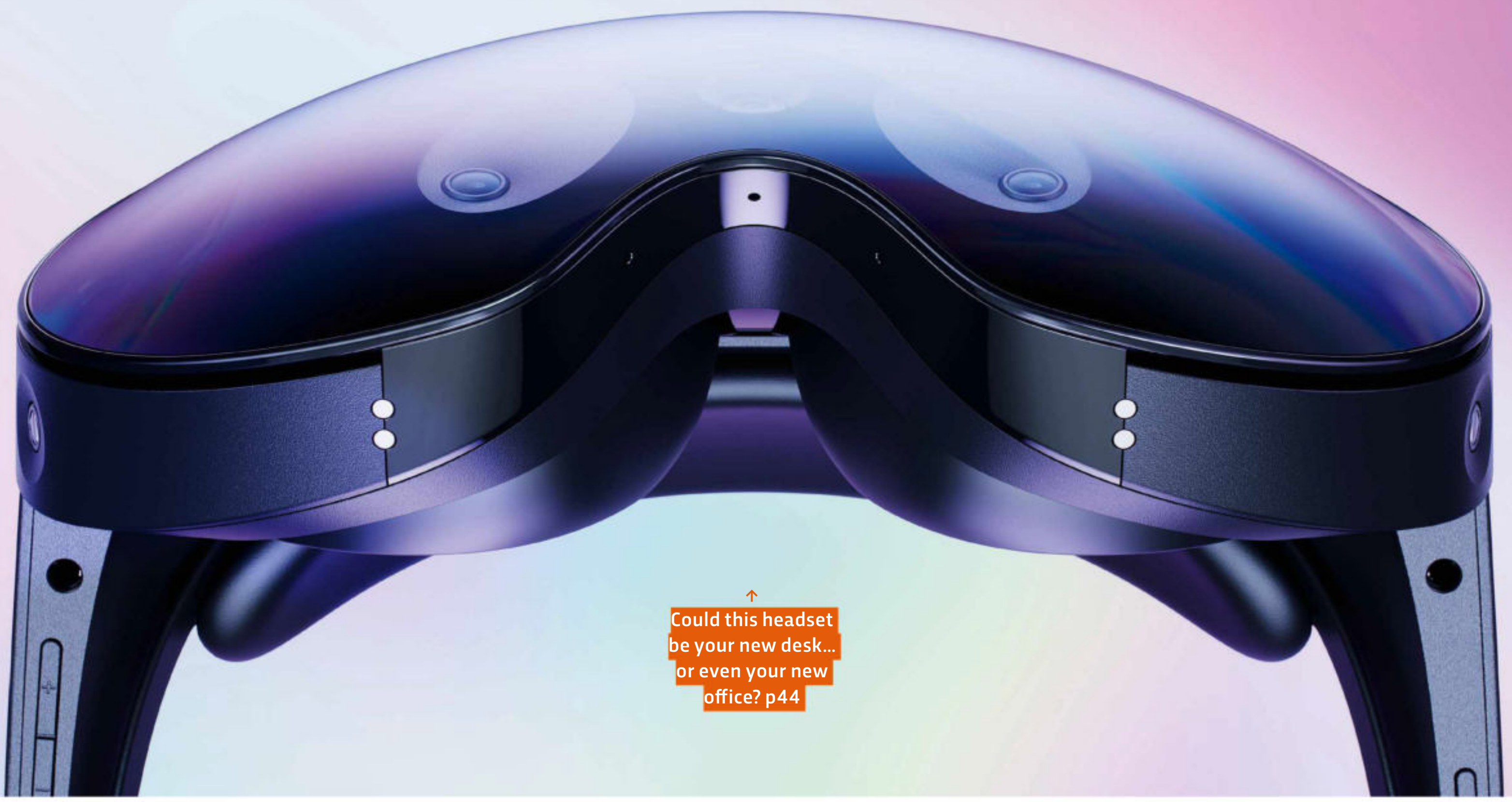
SMART LIGHTS

Transform your home's ambience with these setups **p46**

NEW TECH

IDEAS WE LIKE

Our pick of this month's greatest new gadgets **p48**



Could this headset be your new desk… or even your new office? p44

55% The percentage of VR users that are satisfied with the experience (Thrive Analytics and ARtillery Intelligence)

1 in 3 The number of VR users that have experienced motion sickness (Linde Virtual Academy)

12% Worldwide sales of VR headsets dropped more than 12 per cent in 2022 (NPD Group)

REVIEW

Meta Quest Pro: a VR headset for an unknown customer

The Meta Quest Pro is powerful and full of features, but, as **Alex Hughes** discovers, unless you're already a full believer in the metaverse, it's probably not for you

It's fair to say that, so far, the metaverse hasn't been the resounding success that Mark Zuckerberg and his team at Meta had hoped for. At a time when most people are trying to save money, a VR headset and a patch of virtual land fall low on most people's shopping lists.

That's why Meta isn't gearing its new Quest Pro headset towards most people. As well as being packed with a host of new features, the Quest Pro has higher specs, a sleek new look and a huge price tag of £1,499.99. So who would pay that sort of money for a VR headset? Apparently the famously rich creatives, teachers and office workers of the world... ahem.

Where the cheaper Meta Quest 2 was the fun uncle of the headset world, intended for playing games or learning a VR sport, the Meta Quest Pro is all business, kitted out with virtual offices, desks and art studios.

So is the Meta Quest Pro the future of the office? Or even the ultimate tool for creatives looking to enhance their art? We spent some time with it to see if this VR headset could justify its lofty price.

The Meta Quest Pro lets you alter your workspace to make it virtual

A BLENDED WORLD

The Meta Quest Pro is stylish, futuristic and incredibly uncomfortable. For short periods, it is as comfortable as a chunky VR headset can be; for longer stretches of time, it soon starts to feel heavy.

It also lacks full immersion – you can very clearly see out of the bottom, even when you clip on the eye covers. When I was deep into a game or experience, it wasn't too bad, but it was hard to ignore at other times.

One feature that I loved, however, was the ability to set a walking parameter. Using the controller, I could trace out an area for me to safely move within, saving me from headbutting my bookshelf or kneeing my dining table. Stray outside this area and cameras on the outside of the headset show you your surroundings through the headset's mixed reality feature, which blends the virtual and real worlds.

Inside the headset, there are displays that have a resolution of 1,920 x 1,800 pixels per eye. They use a local dimming backlight system to improve contrast, and refresh at a rate of 90Hz to reduce motion sickness. But battery life is poor, with Meta quoting up to two hours (less than that of the lighter, cheaper Quest 2). So if you're planning to use this for work or creative endeavours, you'll need several charging breaks throughout the day.

START A VIRTUAL NEW LIFE

All set to start living out my *Ready Player One* fantasies, I tried *Horizon Worlds* – a multiplayer virtual platform and Meta's best attempt at a metaverse experience so far. In a nutshell, it's a social gaming platform like *Habbo Hotel* or *Second Life*, but pumped up with voice chat and virtual reality functions.

While the concept is great, it has flaws. It can be glitchy and, quite frankly,

Meta hopes to change the way we work and collaborate with the Quest Pro headset

> "CAMERAS IN THE HEADSET CAN MONITOR YOUR EYES AND MOUTH, AND REPLICATE YOUR EXPRESSIONS IN THE METAVERSE"

confusing. It took me a lot of time to get my head around how to navigate these worlds, even with the lengthy tutorials.

One feature that helps the Meta Quest Pro stand out here is its facial capture facility. Cameras in the headset can monitor your eyes and mouth, and replicate your expressions in the metaverse. This, in theory, means when you smile, your avatar smiles too. In reality, however, mine looked asleep most of the time and laughing made me look like a demented villain attempting to take over the world. Like most other parts of the Meta Quest Pro, this feels like technology that will be useful in the future, but not right now.

Meta is also pushing Horizon Workrooms, the virtual office feature. Unfortunately, using it often felt like doing my job at a lower capacity with extra steps. VR meetings in Horizon Workrooms took forever to organise and felt like a more disorientating version of a Teams or Zoom meeting. Can I see businesses actually hosting meetings in this digital space? No, not really. One part of Horizon Workrooms that performed well for me was the ability to set up a desk to work at. You sit down (at a real-life desk) and use the hand controllers to draw a desk in front of you, creating a replica space in the metaverse. After that, you can connect your computer so you have multiple displays, a nice office, and a fancy desk in the headset, but you type on your real-life keyboard and select files with your real-life mouse.

It worked better than the meeting function, but I couldn't really see the point. Working like this was disorientating, no more comfortable than working at your actual desk and, considering the recharging breaks needed for the battery, no more convenient.

VERDICT

The Meta Quest Pro is easily one of the most powerful VR headsets out there, but so it should be at £1,499.99. The thing I can't understand is, who this headset is actually for?

Few businesses are likely to cough up the cash for a bunch of them and the education system isn't exactly itching to spend this kind of money.

The Meta Quest Pro seems to cater to a market that doesn't exist yet. In the future, maybe we'll be living it up by learning, creating and meeting in the metaverse. But for now, this feels like a headset made purely for the metaverse and VR fanatics who are willing to splash the cash.

RATING

★★★★★

PROS:

- Excellent safety features
- Mixed reality works well
- High-quality visuals
- Eye and head tracking

CONS:

- Short battery life
- Expensive
- VR is still buggy
- Heavy headset

WHAT CAN YOU DO IN THE METAVERSE?

WEDDINGS

Who needs a glamorous venue or a beautiful church when you can have your wedding in the metaverse? Strap on a headset and look into your partner's avatar's eyes as they unemotionally stare back at you at the digital altar. While it's still a new concept, there are already a few people who have done their wedding ceremonies via Meta's *Horizon Worlds*.

BUY LAND

In the real world, it's becoming harder and harder to get onto the property ladder, so perhaps we could all settle for a virtual plot of land instead? A number of websites have appeared recently, offering to sell users land, houses and furniture in the metaverse. These plots of land don't exactly come cheap, so this is more of an investment for the 'more money than sense' crowd.

ATTEND A GIG

Foo Fighters, Justin Bieber and Ariana Grande are just a few of the artists who have already flocked to perform in the metaverse, and realistically, they won't be the last. Virtual performances have been one of the biggest exports of these virtual worlds, offering a futuristic gig from your bedroom. It's similar to the real-life concert experience... just with less beer on the floor and no one shoving into you.

Best smart lighting systems

Bring voice control, mood lighting and a simulated sunrise to your home, says **Alistair Charlton**

Philips Hue starter kit

£134.99, philips-hue.com

Philips Hue offers a huge range of lighting and accessories, from standard bulbs to lighting strips, chandeliers, outdoor lighting, motion sensors, switches, and decorative Edison-style bulbs.

Until recently, every Hue bulb had to be connected wirelessly to a hub, called the Hue Bridge, which plugged into your Wi-Fi router. That is still an option – and is required to unlock full functionality – but the latest generation of Hue bulbs have Bluetooth, for direct control from the smartphone app.

Whichever approach you take, the Hue system is easy to set up and use, with options for gathering lights into groups for simultaneous control, for setting timers and for having your lights simulate a sunrise. Hue's full-colour bulbs can be any colour, brightness and temperature, while the cheaper white bulbs can be adjusted from a cool, bluish white to a warm, orangey glow.

Best for simplicity
PHILIPS
hue

Hive smart bulbs

£19, hivehome.com

Hive sells a huge range of smart home products, including thermostats, plugs, security sensors, hubs and a wide selection of light bulbs. All Hive devices require a hub to function, but only one is needed per home.

Once installed, Hive lighting works via an app, so you can adjust settings, create schedules and design so-called Actions, where several devices can be configured to work together.

In our view, the Hive app isn't quite as slick or intuitive as Hue's, but once you've learned the ropes there's plenty of customisation on offer. Like other systems, Hive also works with Alexa and Google Assistant, so can be controlled with voice commands and integrated into those systems for more advanced smart home automation. Siri Shortcuts and Apple Homekit compatibility is also available, for control from your iPhone, Mac or Apple Watch.

Best for customising

Best for style

Nanoleaf Elements Hexagons

£329.99, nanoleaf.me

Nanoleaf sells light strips and conventional bulbs, but what sets this company apart is its decorative smart lighting. This Elements kit includes 13 hexagonal panels that fit together in any way you like, plug into a wall outlet, and are controlled by app, voice, smart home systems, touch or an included control panel. They can also react to music.

The panels are finished with a wood grain veneer and can change in temperature from cool blue to warm orange.

The minor gripe is that the panels are slightly fiddly to set up, because when you're experimenting with your design on a table or the floor, they come apart quite easily. However, when you're actually attaching them to the wall, the included connectors stay clipped together securely. Phew.

TP-Link Tapo L930-10

£79.99, tapo.com

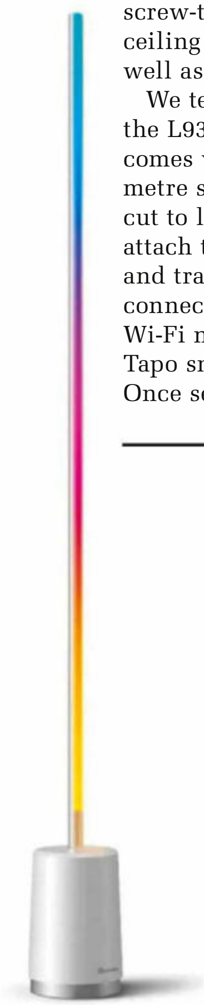
Tapo includes regular, screw-type bulbs and ceiling spotlights, as well as light strips.

We tested a light strip, the L930-10 kit, which comes with two five-metre strips that can be cut to length. Both strips attach to a single plug and transformer, which connect directly to your Wi-Fi network and the Tapo smartphone app. Once set up, they can be integrated with Alexa, Apple Home and Google Home, so you can control them with your voice.

Each strip is split into 50 lighting zones and the app is full of pre-configured modes for several colours at once, or animations that gradually change colour.

We attached the strip under the lower kitchen cupboards, creating the look of expensive fitted lighting for a fraction of the price.

Best for awkward spaces



Govee
RGBICWW Floor Lamp
WiFi

Best for dingy corners

Govee Lyra

£149.99, uk.govee.com

Not all smart lights come in the form of bulbs or wall attachments, another popular option is to invest in a smart floor lamp. The Lyra floor lamp comes complete with voice control through Alexa or Google.

The lamp is a simple and unobtrusive design, with a short white base and a long pole reaching out of the top. The lamp offers you the choice of 64 different light effects, and can also respond reactively to music.

Just like its competitors, Govee offers a detailed app for you to edit the lights and set schedules for when you want the lamp to turn on.

However, considering this is just one light, it is by no means the cheapest way to get set up with a smart lighting system. Look out for any discounts or sales, if you want to get a better price.

Ideas we like...

Our pick of the month's smartest tech

↓

...a comfier VR experience

Among the many issues with virtual reality, one that comes up time and time again is just how uncomfortable the headsets can be, because of both their size and weight. Ironically, a company called Bigscreen has solved this problem with what they claim is the world's smallest VR headset. Weighing just 127g, this headset is incredibly light, and is custom-built for your face. Of course, to get the device this small, sacrifices will have had to be made, and only time will tell if this is the future… or yet another failure in virtual reality.

Bigscreen Beyond
£1,149, store.bigscreenvr.com

↓ ...IKEA breaks into health tech

IKEA is no longer just known for cheap furniture and complicated instructions that leave you sobbing on your living room floor. The brand has seen a rapid move into audio and smart devices, with the latest creation being the VINDSTYRKA. IKEA claims that this smart meter can measure your home's air quality, humidity and temperature. It can be connected to other smart devices, like air purifiers, heaters and dehumidifiers.

IKEA VINDSTYRKA
£TBC, ikea.com

↓ ...a smart telescope for city living

To help urbanites to better see the stars, Unistellar has created the eQuinox 2, a telescope that uses advanced image processing to filter out the effects of city lights. It creates a clear, high-res image, so viewers can peer at stars millions of light-years away. Sure, it isn't cheap, but when you consider that it's 4.5 million times cheaper than the James Webb Space Telescope, it's *kind* of a bargain.

eQuinox 2
£2,199, shop.uk.unistellar.com

↓ ...RC cars enter mixed reality

The new remote-controlled vehicles from Hot Wheels can drift, flip, change colour and even shoot flames. They can do this thanks to mixed reality. You control the camera-equipped cars, and as they zoom around your house, you get a first-person view on your iPhone, iPad or PlayStation-enabled TV screen, where jumps, speed boosts and other graphical effects combine to offer an immersive, exciting racing experience. And yes, they work on carpet.

Rift Rally
$129.99 (£108 approx), riftrally.com

↓ ...a wireless TV experience

Companies are doing everything in their power to make televisions more aesthetically pleasing. In the case of Displace, they've removed any trace of wires from their TV. The television is powered by a battery, and uses a wireless box to stream content. As one last party trick, it attaches to any wall or surface in your home via a suction cup, eliminating the need for any messy mounting setups.

Displace TV
£TBC, displace.tv

IDEAS WE DON'T LIKE...

...OVERPRICED LIMITED-EDITION HEADPHONES

Bang & Olufsen's new earbuds offer the unique ability to be in an elite club, albeit a club of people who may have overpaid for a pair of earbuds. The Beoplay EX Atelier Editions are described as 'ultra-rare', and while Bang & Olufsen hasn't stated the exact number available, getting a pair requires a reservation and a high probability of being turned down. So, what is so unique about these headphones? Well, they're green... oh, and they cost €300 more than the same earbuds in any other colour. But hey, at least you'll be in that elite club!

Beoplay EX Atelier
€699 (£620 approx),
bang-olufsen.com

...A CONFUSED WEARABLE IN A CROWDED MARKET

"Time is now. Don't miss a moment" lists the website of NOWATCH in large bold text, just in case you were unsure on the concept of time. The NOWATCH looks just like a watch, except it is lacking the very fundamental ability to tell the time. Instead, this device is all about health tracking, measuring your breath and heart rate, skin conductance and movement. At a similar price to a premium Apple Watch or other leading wearable, this is a case of style over substance.

NOWATCH Atelier
€458 (£406 approx),
shop.nowatch.com

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TIRED ALL THE TIME?

THE MYSTERY OF THE BIGGEST BLACK HOLE IN THE UNIVERSE

Black holes are big. Very big. But physics makes it almost impossible for them to grow. Here's how one black hole defied the odds to swell to gargantuan proportions

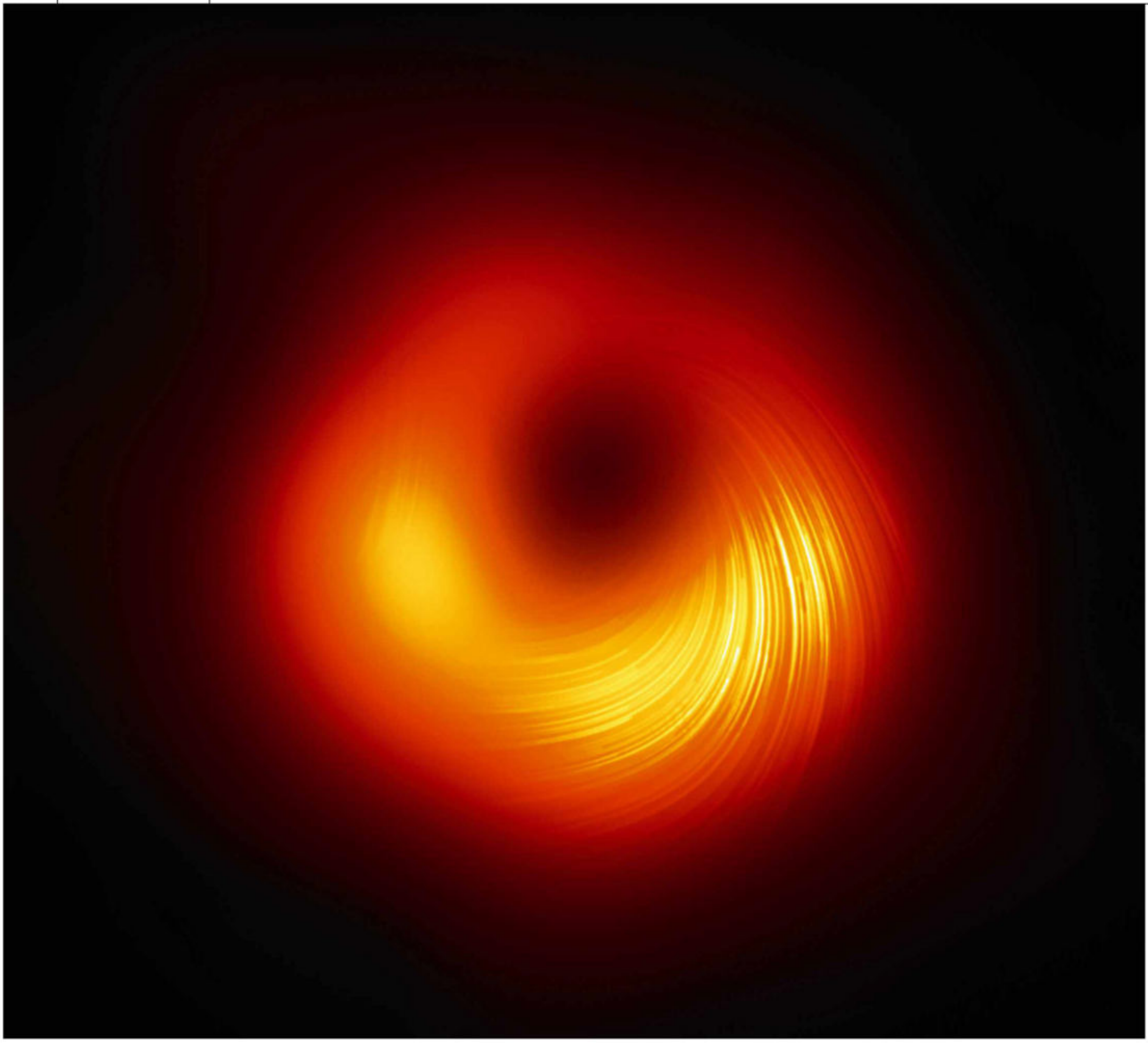
by DR BECKY SMETHURST

ILLUSTRATION: ANDY POTTS

The first image taken of a black hole, the picture that finally turned artists' impressions into a reality, was of the supermassive black hole at the centre of the galaxy Messier 87. Most supermassive black holes are found in the centres of galaxies. They sit in the gravitational driving seat as the hundreds of billions of stars in the surrounding systems happily orbit them, just like the planets orbit the Sun at the centre of our Solar System.

The black hole at the centre of Messier 87 lies at the more massive end of the supermassive scale, cramming a mass that's six billion times that of the Sun (six billion solar masses) into an area the size of Neptune's orbit. But as huge as that might sound (especially when compared to the black hole at the centre of the Milky Way, which is a mere four million solar masses), it's by no means the most massive black hole that we know of.

That title goes to TON 618, which is an astonishing 66 billion solar masses. It's so big that astronomers had to invent a new term to describe it; hence, TON 618 is what's become known as an ultramassive black hole. →



ABOVE Messier 87 was the first black hole to be imaged, a feat made possible by scientists creating a virtual telescope as large as Earth, named the Event Horizon Telescope

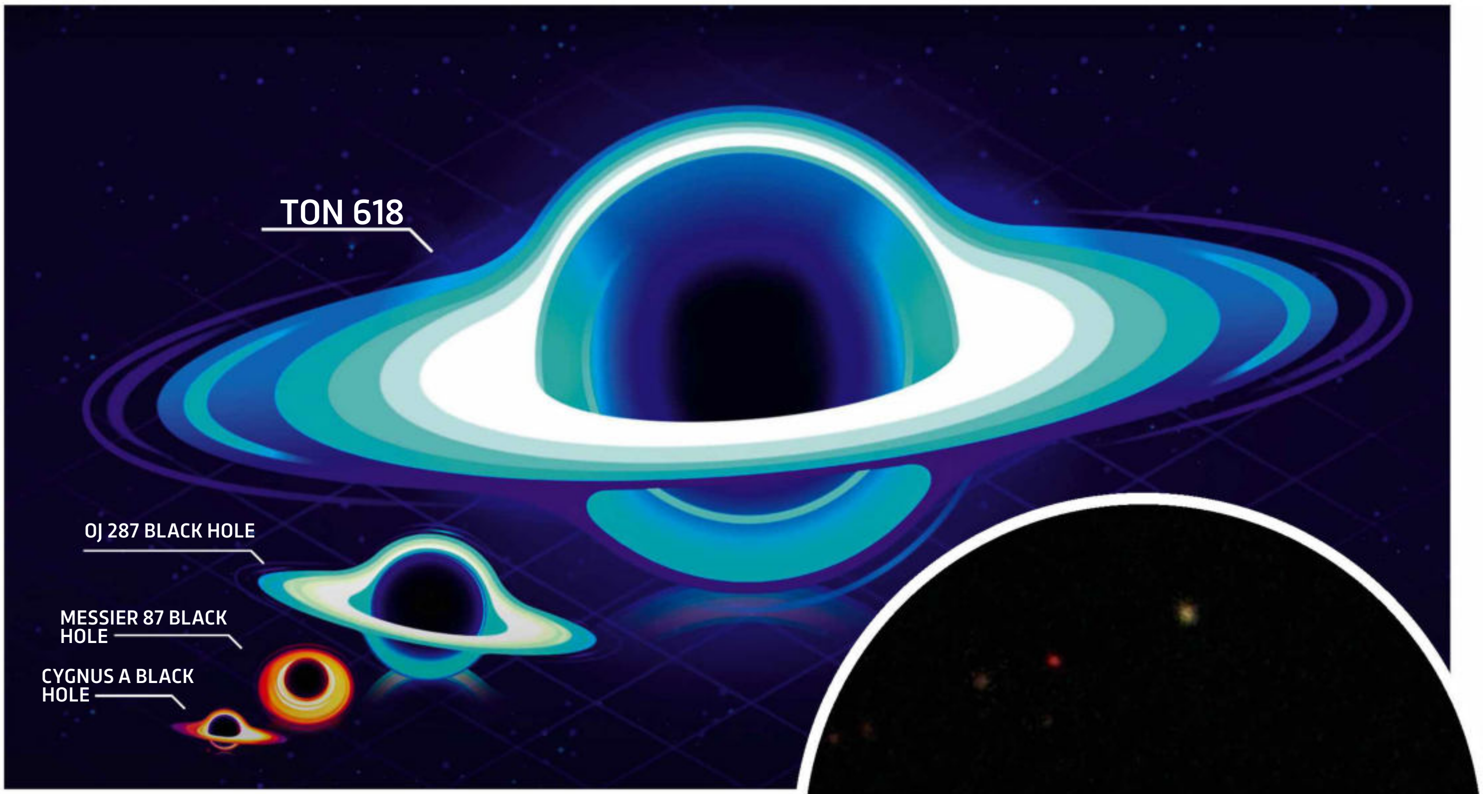
→ To give you an idea of just how mind-bogglingly big TON 618 is, imagine taking all the stars in the Milky Way and squishing the matter in them down to create a black hole. Even if you did that, you would still be a few billion Suns' worth of matter shy. So how did TON 618 become such a behemoth?

SPAGHETTI AND PIZZA

Black holes are made of vast amounts of matter that have accumulated in one spot and been packed together as densely as possible, to the point where the gravitational pull from the accumulation is so strong that not even light can escape it.

But that doesn't mean that a black hole is a giant monster with an insatiable appetite, roaming the Universe and devouring everything it encounters. TON 618, the most massive black hole we know of, still has an entire galaxy of stars happily orbiting it and not getting sucked in. It's a common misconception that black holes act like vacuum cleaners, when in reality it's incredibly difficult to grow a black hole. For a start, you have to get material close enough for it to be affected by the black hole's gravity. And when you consider how dense black holes are, due to all that matter being squashed into such a tiny space, and how vast the Universe really is, you start to realise just how difficult that can be.

If matter does stray too close, however, it will get pulled in by the black hole's gravity and that gravity increases dramatically the closer you get. Think of it like walking up a hill, but the hill becomes steeper with every step you take. It's brutal. The



> **“IF YOU CROSS THE EVENT HORIZON, YOU’RE DONE FOR, OFFICIALLY PART OF THE BLACK HOLE FOR EVERMORE”**

gravity around a black hole increases so quickly that if you were to approach one with your feet first, the pull of gravity at your feet would be so much stronger than at your head that you’d get stretched out like spaghetti. (In perhaps the best example of jargon the science world has to offer, the process is legitimately referred to as ‘spaghettification’.) We see this happening to stars and clouds of gas as they get close to a black hole.

Once spaghettified, the matter then gets pulled into orbit around the black hole and flattened out into a swirling disc of material. The process is similar to the way you create a pizza base by tossing the dough above your head – as it spins, the dough gradually flattens out. Once it’s in that spinning disc, the matter (usually hydrogen gas as this is the most common element in the Universe) will settle into a nice, happy orbit around the black hole, far away from the point of no return: the event horizon.

TOP A size comparison showing how TON 618 dwarfs some of the other known black holes

INSET The blue-white quasar, located just below the centre of the image, was captured by the Sloan Digital Sky Survey. It indicates the position of TON 618

The event horizon is the sphere around the black hole that we use to ascertain its size; the larger the event horizon, the more massive the black hole. While the matter inside the event horizon is being crushed down into an infinitesimally small space, known as the singularity, the size of a black hole is taken to be the region of space from which we no longer receive any light. It’s the distance away from the singularity where you’d have to be travelling faster than the speed of light to escape the black hole’s gravity. If you cross the event horizon, you’re done for, officially part of the black hole and contributing to its total mass for evermore. →

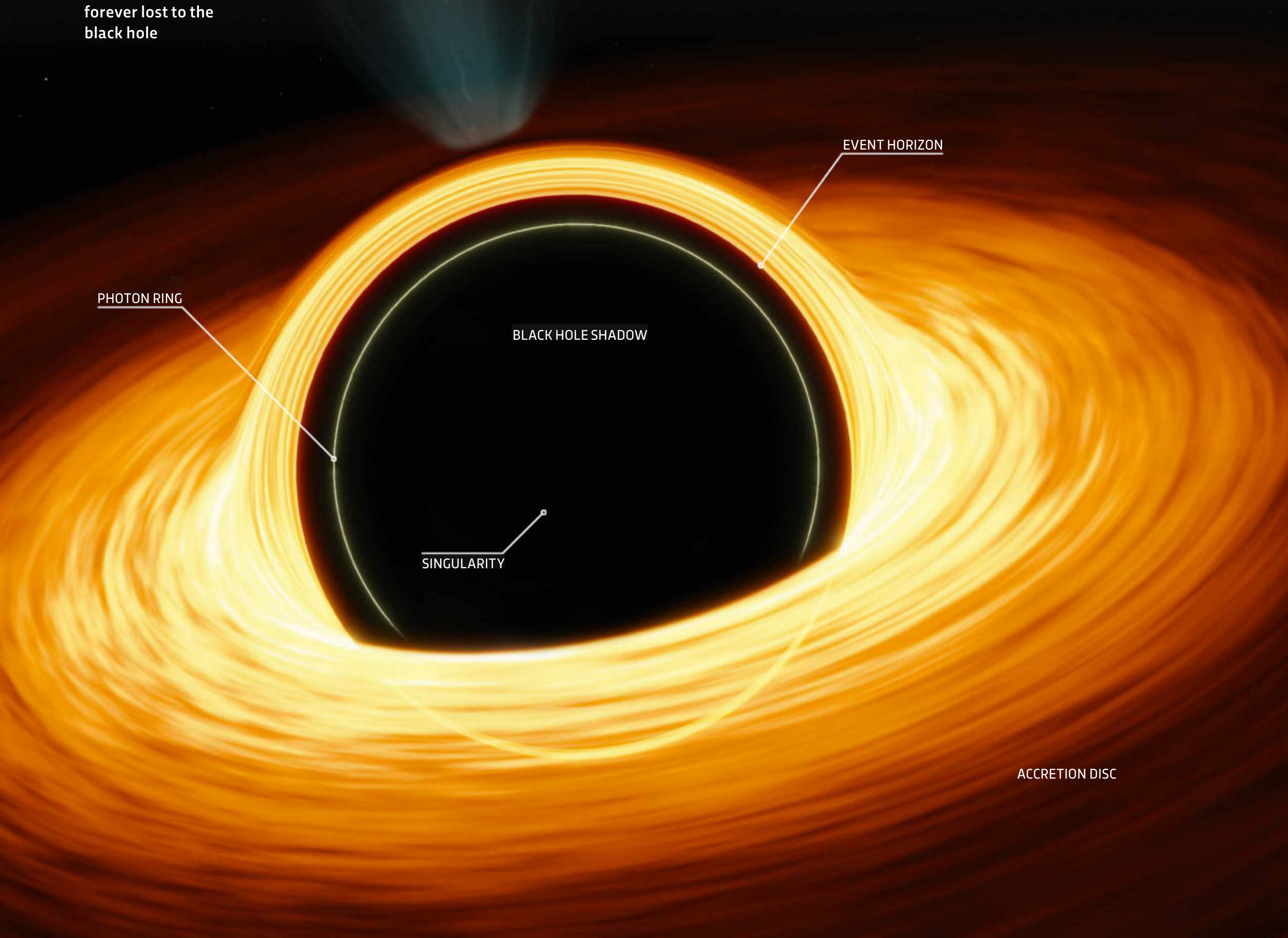
ESO/EHT, KURZGESAGT GMBH, SLOAN DIGITAL SKY SURVEY

> **“BUT GETTING MATTER TO CROSS THE EVENT HORIZON IS WHAT’S SO DIFFICULT ABOUT GROWING BLACK HOLES”**

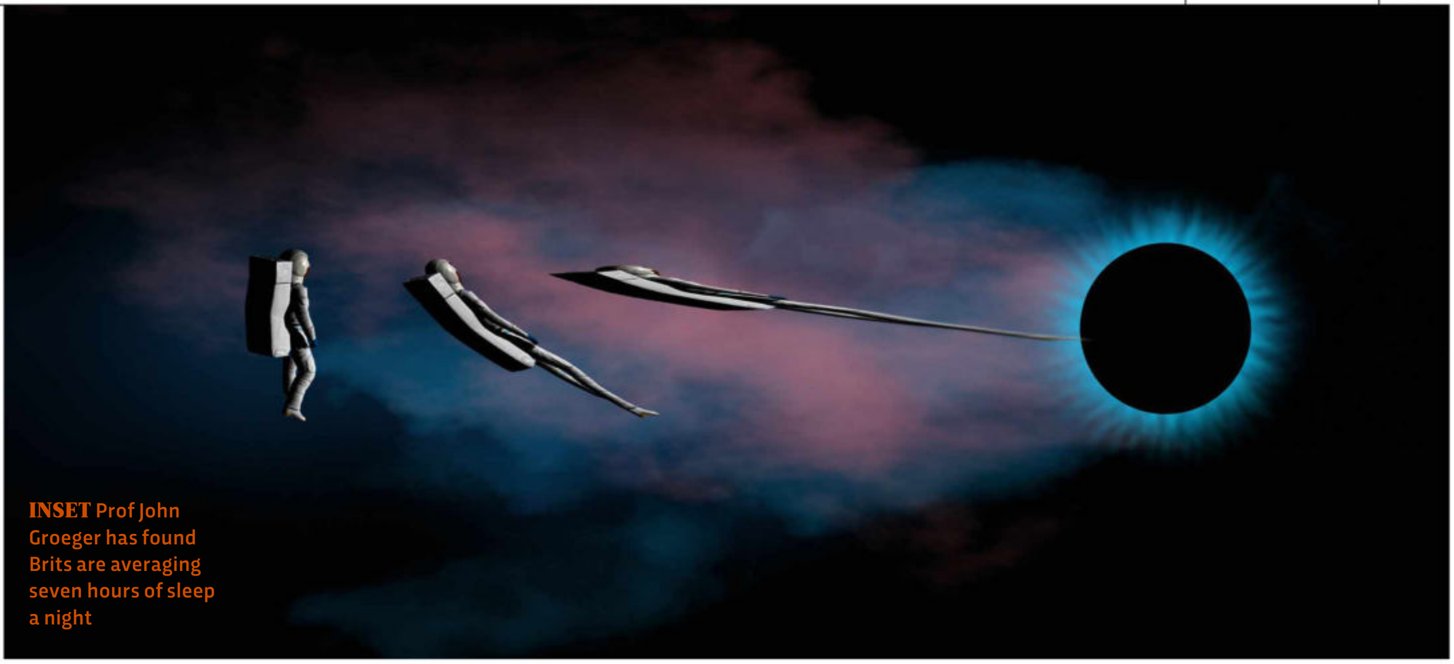
→ But getting matter to cross the event horizon is what’s so difficult about growing black holes. How do you move material out of a happy, stable orbit around the black hole and get it to ‘fall in’, helping the black hole swell to massive proportions? The Sun and Earth provide a good demonstration of the difficulty. Earth is on a stable orbit around the Sun and despite the star’s huge size and far greater gravity compared to our planet, it’s thankfully unable to pull us in towards it.

FALLING IN

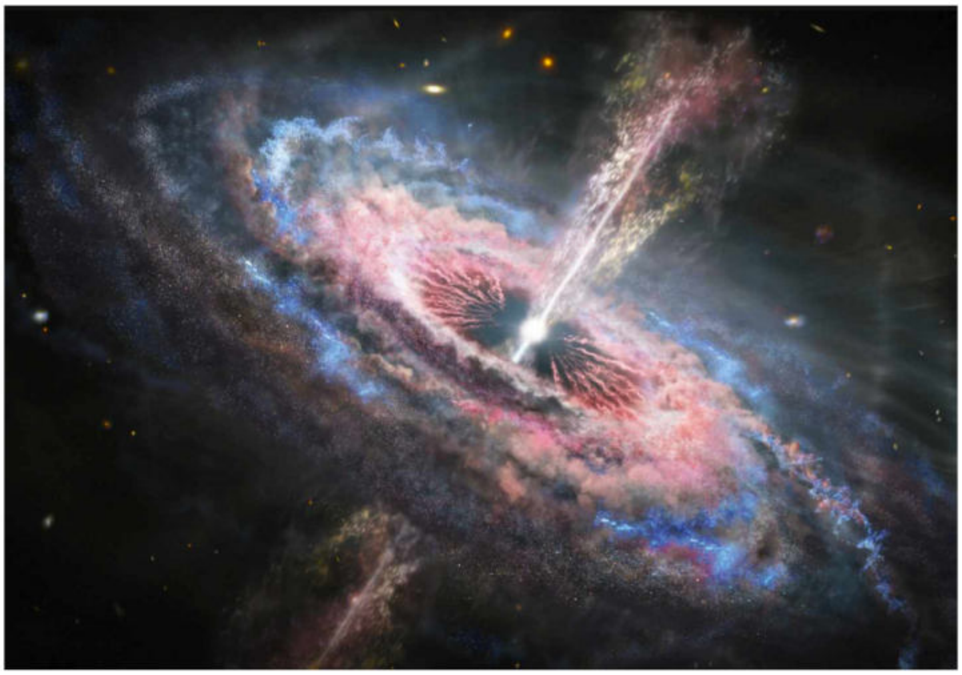
The reason material is able to cross the event horizon is collisions between particles in the disc of material orbiting it. Atoms of hydrogen gas collide and transfer energy, just like balls on a snooker table. If you’re a talented snooker player you might be able to hit the cue ball against a coloured ball and get the cue ball to stop dead, transferring all of its energy to the coloured ball, which shoots off across the table. A similar exchange in energy can happen to colliding particles in the disc of material orbiting a black hole; the particle that gains all the energy will get a boost, pushing it further away from the black hole. But the particle that loses its energy will have nothing to resist the gravity pulling on it, and gradually slide down to cross the event horizon and become part of the black hole.



Once material from the accretion disc crosses the event horizon, it’s forever lost to the black hole



INSET Prof John Groeger has found Brits are averaging seven hours of sleep a night



TOP The pull of gravity towards a black hole increases so quickly that objects caught in it get spaghettified

ABOVE The luminosity of the material orbiting a black hole gave rise to the notion of quasars: stars that aren't stars

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Not every collision will result in such a drastic energy exchange; on average there'll be an equalling out of the energy. But eventually, one particle will have enough collisions and be unlucky enough to lose energy in every one, bringing it ever closer to the black hole. It's only when the particle has a collision in the region known as the 'innermost stable circular orbit' (ISCO) that it will finally cross the event horizon to become a part of the black hole.

The ISCO doesn't exist in Newton's theory of gravity, which we all learn at school. Newton's theory says that all perfectly circular orbits, no matter their distance, are very stable. That means if an object on a circular orbit is unsettled slightly, it'll remain largely on the same orbital path. For instance, if something was somehow orbiting near the Sun in a perfect circle and was nudged by another object, its orbit might become more oval, but it would continue orbiting the Sun.

That's not the case in Einstein's theory of relativity, however. As you get closer to an object like a black hole, there comes a point where, if you nudge an object on a circular orbit – or, say, one particle were to collide with another – that object couldn't correct its path and would end up spiralling in towards the black hole. That point is the ISCO. It lies around three times further out than the event horizon and, usually, marks the inner edge of the orbiting disc of matter. This process of particles colliding, exchanging energy and falling over the event horizon – accretion – takes a very long time. We're talking millions of years just to get a black hole to a size where it can snack on a passing gas cloud that drifts too close.

TURNING FOOD AWAY

Complicating matters even further is the fact that there's also a limit to how much matter a black hole can accrete in a given time. The Universe effectively puts a black hole on a diet if it becomes too gluttonous.

This happens because the disc of matter orbiting a black hole is moving and colliding at such an incredible speed, that it starts to heat up due to friction. It's heated to such an extreme temperature that it glows like metal in a forge.

The good news about this glow is that it allows us to spot black holes and measure how massive they are. The light can, and does, outshine entire galaxies, making them look like single pinpricks of light. →

→ These pinpricks were originally dubbed quasars, a portmanteau of quasi-stellar, because they look like stars but aren't stars. (It was only after the Hubble Space Telescope launched in the early 1990s that astronomers could make out the galaxy of stars that went with each quasar and their true role in growing supermassive black holes was revealed.)

The bad news for black holes is that the glow is so intense that it exerts a pressure outwards (radiation pressure) that prevents any more matter from falling in. If there's too much material in the disc, the radiation pressure increases and pushes material away from the black hole. There's a fine balance between the size of the black hole and the quantity of matter in its disc, and when a certain threshold is reached (depending on how massive the black hole is) the rate at which it can accrete material is capped.

SO HOW BIG CAN BLACK HOLES GET?

What makes TON 618 so exceptional is the sheer amount of physics standing in the way of a black hole growing to that size. But while we've known for a long time that radiation pressure places a limit on how fast a black hole can grow (known as the Eddington limit, after astronomer Sir Arthur Eddington), what we didn't know until recently was whether there's a limit to how massive a black hole can become.

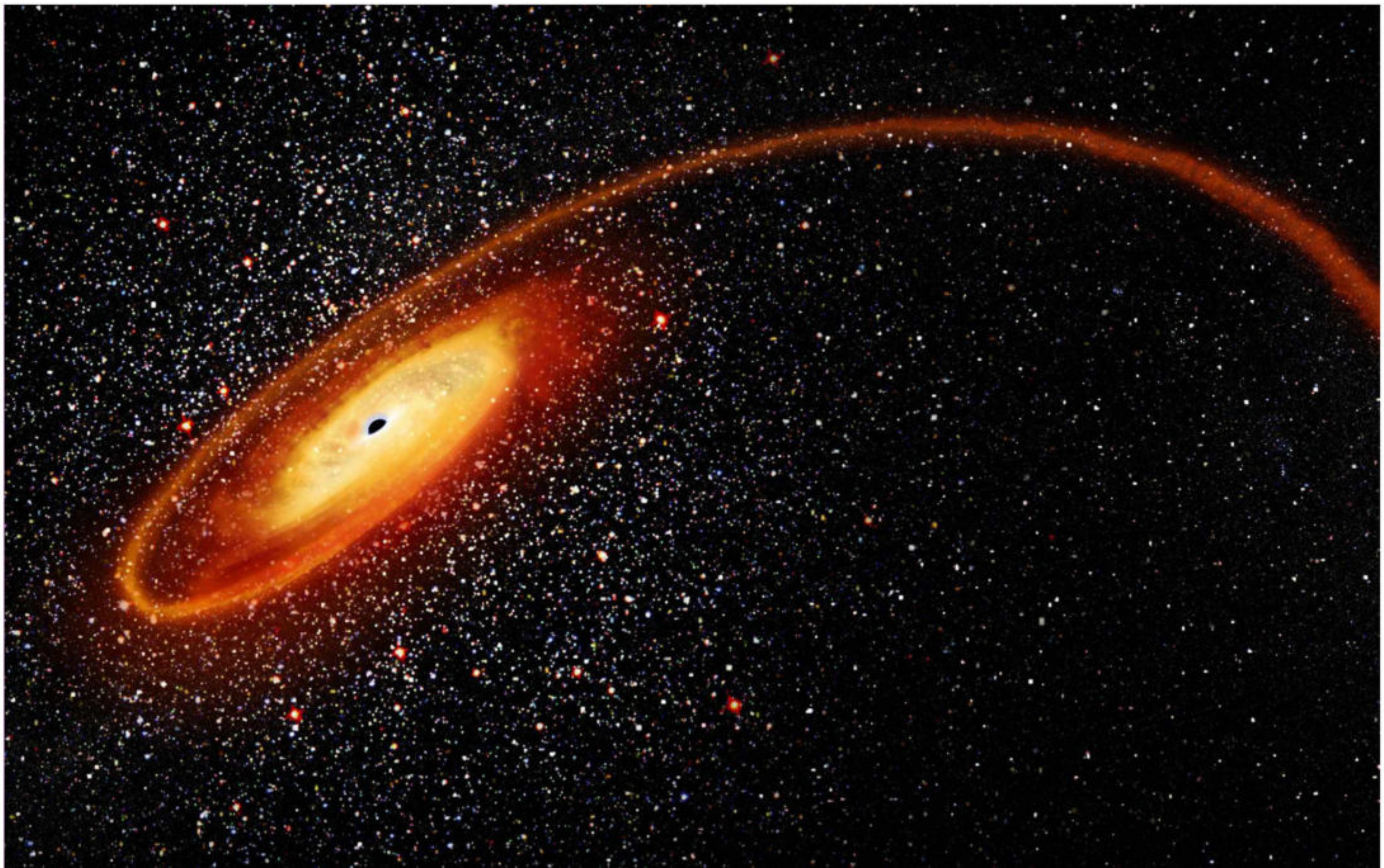
As far as we know, there isn't. Theoretically, you could keep on merging black holes to your heart's content, gradually increasing the overall size, as if you were making a giant snowball. But there is a limit to how big black holes can grow via accretion.

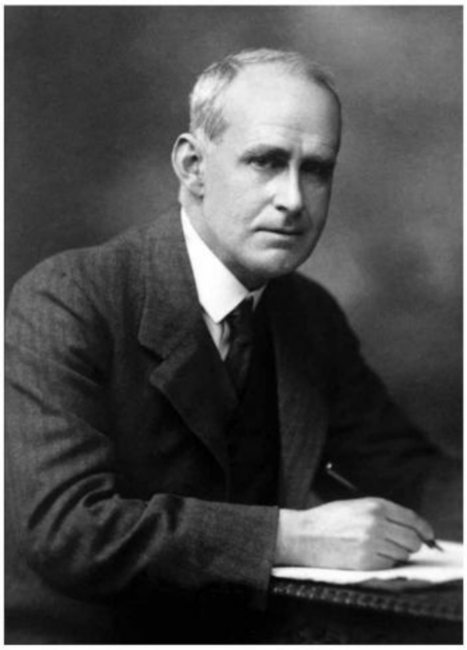
In 2015, Prof Andrew King at the University of Leicester published a paper that pointed out a quirk of gravity around black holes. The quirk allowed him to estimate the maximum mass a black hole could achieve via accretion: 50 billion solar masses (but it could be 270 billion solar masses if the black hole was spinning fast in the same direction as its galaxy). At the root of this quirk is the position of the ISCO, which, like the event horizon, is related to how massive the black hole is. As the black hole's mass increases, the ISCO gets pushed further out.

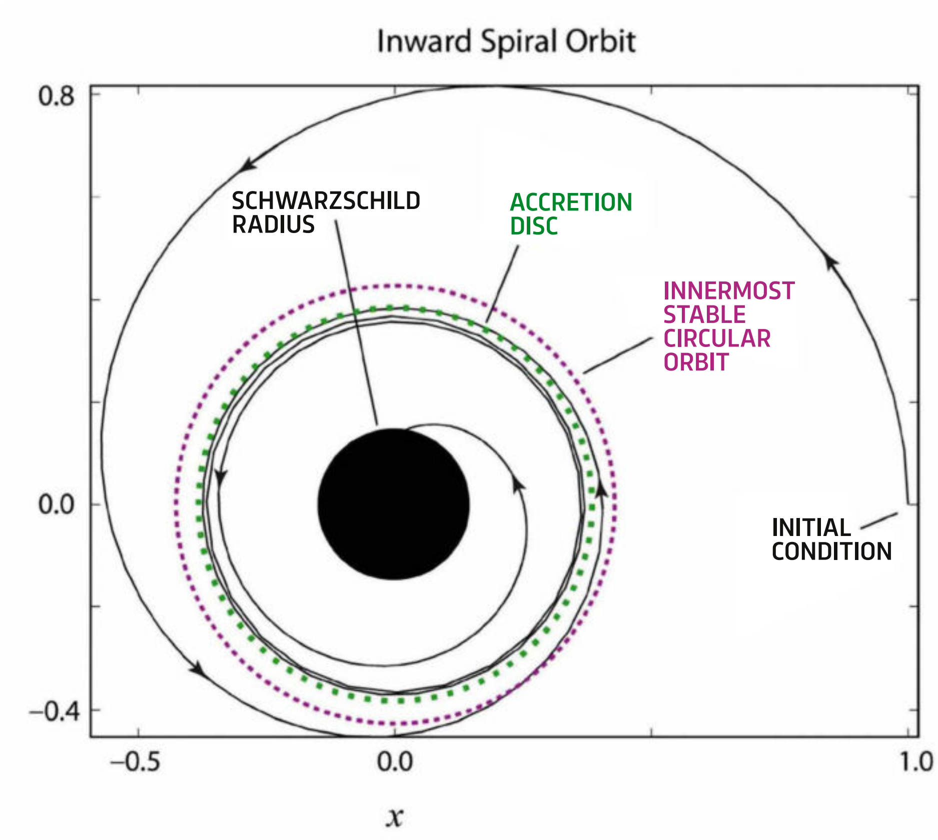
The problem for a growing black hole is when the ISCO is pushed beyond what's known as the 'self-gravitational radius'.

> **"THEORETICALLY, YOU COULD KEEP ON MERGING BLACK HOLES TO YOUR HEART'S CONTENT, GRADUALLY INCREASING THE OVERALL SIZE, AS IF YOU WERE MAKING A GIANT SNOWBALL"**

BELOW Material from a nearby star being pulled into the orbit of a black hole







The distance that the self-gravitational radius sits around a black hole is another factor that's related to the mass of the black hole, but it also depends on the object that's approaching it. The self-gravitational radius marks the point at which the pull of gravity holding the approaching object together (self-gravity) is stronger than the pull from the black hole.

The self-gravitational radius is why we're all here. It's why we're able to have entire galaxies surrounding supermassive black holes; beyond this radius, gas in a galaxy is attracted more to itself than to the black hole lying at its centre. If this wasn't the case, gas would never collapse to form stars and instead our atoms would just be part of one giant disc of material orbiting a supermassive black hole.

It was King who pointed out that when a black hole reaches 50 billion solar masses, the ISCO gets pushed beyond the self-gravitational radius. What that means is that, no matter how many collisions they have, any particles in the disc of material orbiting the black hole will never lose enough energy to reduce their orbit to a point that allows them to reach the ISCO and spiral into the black hole. Instead, the pull of gravity from all the other particles in the disc will always be stronger than the pull from the black hole. That's if there even is a disc of material around the black hole – because any matter that isn't on a direct, 'bullseye' trajectory with the singularity as it approaches, won't get pulled into a disc. Instead it will loop around the black hole, spaghettified, but otherwise unscathed. This lack of a disc means that we also won't be able to spot such a black hole, as there'll be no luminous matter around it lighting up like a Christmas tree.

This is why TON 618 is so interesting to astronomers: with an ultramassive black hole of 66 billion solar masses, it lies above King's estimate of the maximum limit (50 billion solar masses) for a non-spinning black hole. Most black holes are spinning, which increases the mass they can reach before they push the ISCO beyond the self-gravitational radius, but it still means that TON 618 could be nearing its maximum possible mass.

PAST THEIR PRIME

It's fascinating to consider the implications of all this. We could be approaching the point in the Universe's history in which black holes start reaching their limit. If black holes stop accreting and growing in this way, then they'll also stop glowing. Quasars will begin to wink out as black holes age past their glory days.

It's possible that there are other black holes in the Universe that have already reached ultramassive proportions. We can try hunting for them, but without the glow of a disc orbiting around them, we'll never spot them. There could even be ultramassive black holes hiding right under our noses… **SF**

ABOVE Once an object falls within the innermost stable circular orbit, it inevitably spirals into the black hole

ABOVE LEFT Sir Arthur Eddington never accepted the idea that stars could collapse into black holes. But his name is now associated with a process that governs their growth

by **DR BECKY SMETHURST**
Becky is an astrophysicist at the University of Oxford and the author of A Brief History Of Black Holes *(£20, Macmillan).*

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OREGON STATE POLICE DEPARTMENT

THE WONDERFUL WORLD OF SLIME

Runny noses, slippery sea creatures and that impossible-to-clean bit behind your sink all have one thing in common: slime. While it might make us cringe, life on Earth would be very different without it

by SUSANNE WEDLICH

On 13 July 2017, the apocalypse hit Oregon and it looked like an almighty sneeze. A lorry had overturned and dumped its gooey cargo on a section of Highway 101. Slime covered the road surface, and a couple of vehicles got caught up in the gunk (see previous page). And as if that wasn't bad enough, the snot was teeming with hundreds of eel-like creatures: hagfish.

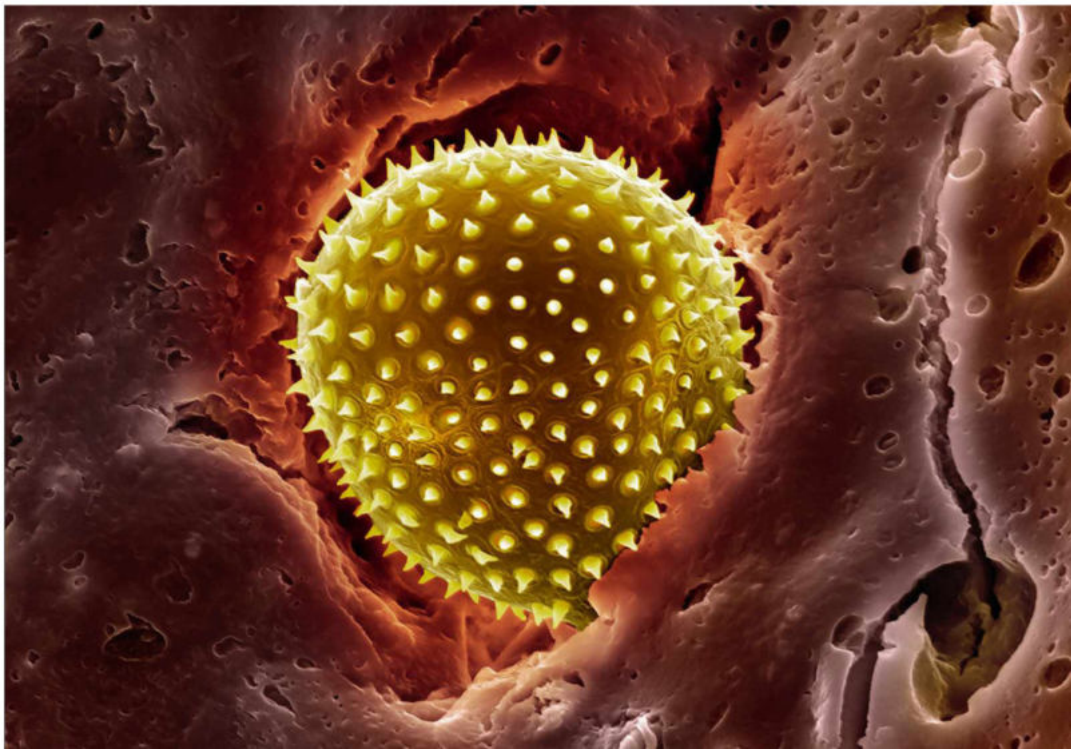
There are many outlandish life forms on the planet and then there is the hagfish. This ancient vertebrate tunnels its way through the carcasses of dead animals, feasting on their flesh. It has no jaws, a double row of pointy teeth, and very simple eyes. Yet these peculiarities pale in comparison to the hagfish's unique defence mechanism.

Stowed away in their skin are slime glands from which the hagfish release a slime precursor. This is made up of molecules called mucins, and long, tightly coiled protein threads. When released, the mucins bind with seawater and expand, while the threads unravel in milliseconds. Together, they weave a textured slime that's tough enough to gag a shark, clog its gills and scare it away. To stop itself becoming trapped in its own goo, the hagfish can tie a knot in its body and slide it from head to tail, wiping off the slime as it goes.

LIFE OF SLIME

If the hagfish is the champion of slime, the rest of creation comes in a close second. Microbes, plants, fungi and animals all use, produce and need slime for protection and defence, to move and mate, to communicate and catch prey. Even seemingly simple organisms have come up with ingenious slime solutions, whether they live on land or in the sea.

Velvet worms, for example, are slow creatures that walk on stubby legs. But they don't need speed to catch their prey; instead, they'll fire long streams of slime from cannons on each side of their head. The goo hardens so fast that there is no chance of escape. Bola spiders favour a similar approach, but instead they swing



TOP LEFT An insect is ensnared in the slime of a velvet worm

MIDDLE LEFT Hagfish create copious amounts of thick goo

BOTTOM LEFT Pollen trapped in mucus in a human nose

sticky silk fibres to lasso their prey.

But slime isn't just a trap, it can be a refuge as well. For example, when a parrotfish wants a nap, it will secrete mucus from its gills, which it uses to form a cocoon around its body to keep parasites and predators away.

Slime can even be a home: edible-nest swiftlets build cup-shaped structures from their saliva that hardens to form a nest in which the birds can rear their chicks.

Without slime, life on Earth clearly wouldn't be the same. Yet there seems to be a woeful lack of research about slime. One possible explanation is that slime is delicate and hard to study, and it operates mostly hidden from view, unless demand is high and production is ramped up until it spills over. Which begs the question: what is slime anyway?

According to retired German microbiologist Dr Hans-Curt Flemming, slime is just "stiff water". He sees biological slime not as a specific substance, but as a quality that materials can have. The characteristic ooziness is based on a particular structure, though. Biological slimes are so-called hydrogels. They consist of more than 95 per cent water that is bound in a 3D network of molecules. Slimes are basically just water in chains.

But those molecules that make up the remaining 5 per cent of slime make all the difference. Pure water can be stirred without ever changing its behaviour. Slime, in comparison, is neither fully solid nor liquid but somehow both at the same time. And it's adaptable too. The right kind of mechanical stress can change its behaviour and properties, making it more liquid or solid. Frogs know how to use this when they hit prey animals with their long tongue. Their saliva liquefies on impact, running into every cranny on the prey's body. Once the tongue pulls back, the saliva becomes viscous and stickier. The hapless prey is firmly glued to the tongue and forced to bungee jump right into the frog's mouth.

The molecules that give slime these properties are called 'mucins', and they are evolutionarily ancient. All animals – from jellyfish to frogs, from snails to fish, from birds to mammals – use them in their bodily goo. Mucin molecules vaguely resemble a bottlebrush, with an elongated protein acting as the handle, and sugar chains called glycans as the bristles. These glycans bind to water and help make slime.

STICKY SITUATION

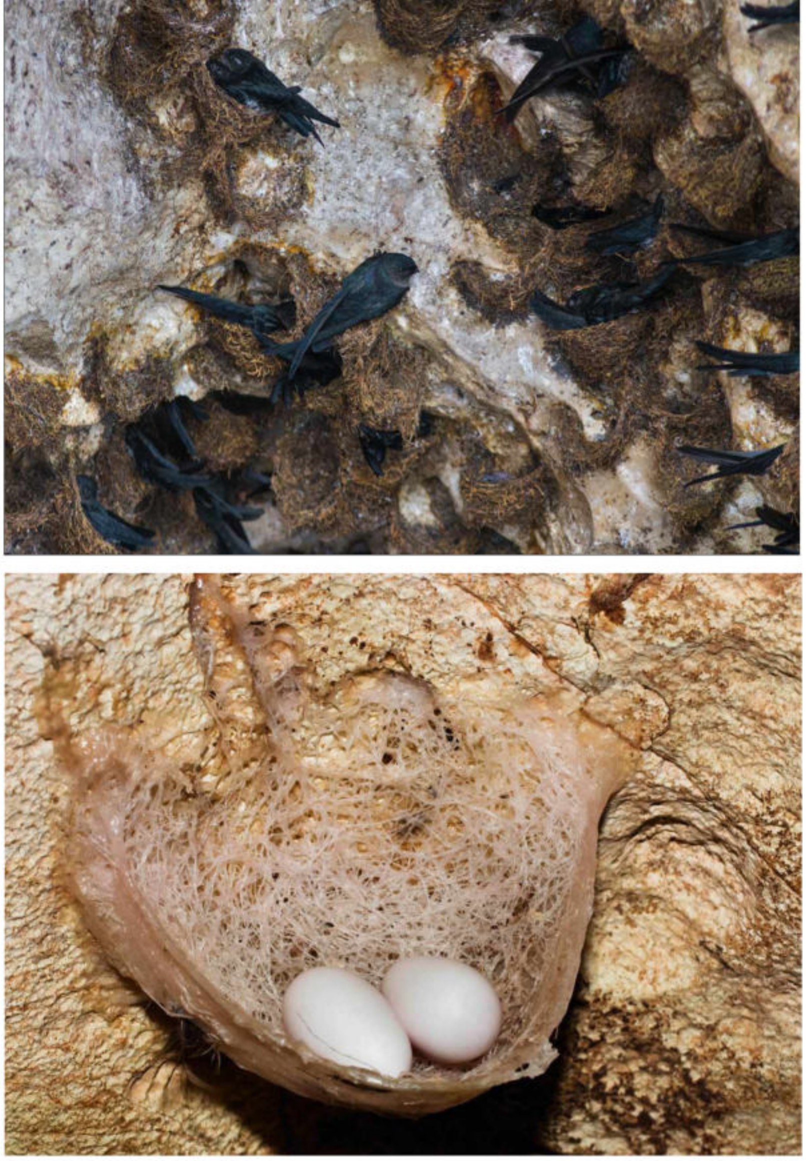
Slime is often found at interfaces where organisms are exposed to the environment. In the human body, for example, mucus coats the surfaces of the airways, and the digestive and genital tracts. These parts of our bodies are entry points for things like respiratory gases and nutrients, but are also vulnerable to potentially harmful particles and microbes. Mucus, here, offers the first line of defence. As a barrier, it beats back germs. As a filter, it chooses what to admit into the body. And the mucus in the colon has one more job: it houses trillions of beneficial microbes, the gut microbiota.

> "THE HAPLESS PREY IS FIRMLY GLUED TO THE TONGUE AND FORCED TO BUNGEE JUMP RIGHT INTO THE FROG'S MOUTH"

How do you fight off pathogens while also accommodating hordes of microbes? You compartmentalise. Researcher Prof Gunnar Hansson at the University of Gothenburg is an expert on all things mucus. He has shown that the mucus in the →

BELOW Common limpets will follow their slime trails back home before the tide goes out

MORLEY READ/NATUREPL.COM, GETTY IMAGES, SCIENCE PHOTO LIBRARY, NICK UPTON/NATUREPL.COM



ABOVE RIGHT
Edible-nest swiftlets live in colonies and make their nests from saliva, which solidifies into a tough material

SUZI ESZTERHAS/NATUREPL.COM, REINHARD DIRSCHERL/MINDEN PICTURES, ALAMY

> **"WE WILL FIND LIFE ON OTHER PLANETS. IT WILL HAPPEN SOON AND IT'S GOING TO BE SLIME"**

→ colon has two layers. The first layer lines the tissue and is a formidable barrier to all microbes, be they beneficial or harmful. The mucus on top of that is more welcoming: a home for the microbiota. Hansson's work has proved how sophisticated goo can be – and how our bodies live in peaceful coexistence with a multitude of microbes. "This was a real breakthrough in the field," Hansson says.

And there's another breakthrough on the way. Prof Katharina Ribbeck, a scientist at MIT, has analysed the interactions between the glycans on the mucin molecules and microbes. She has found the same pattern in the mouth, the lungs and the gut: mucus domesticates microbes. The glycans keep the microbes in check, preventing them from becoming too numerous or dangerous.

EARTH AND BEYOND

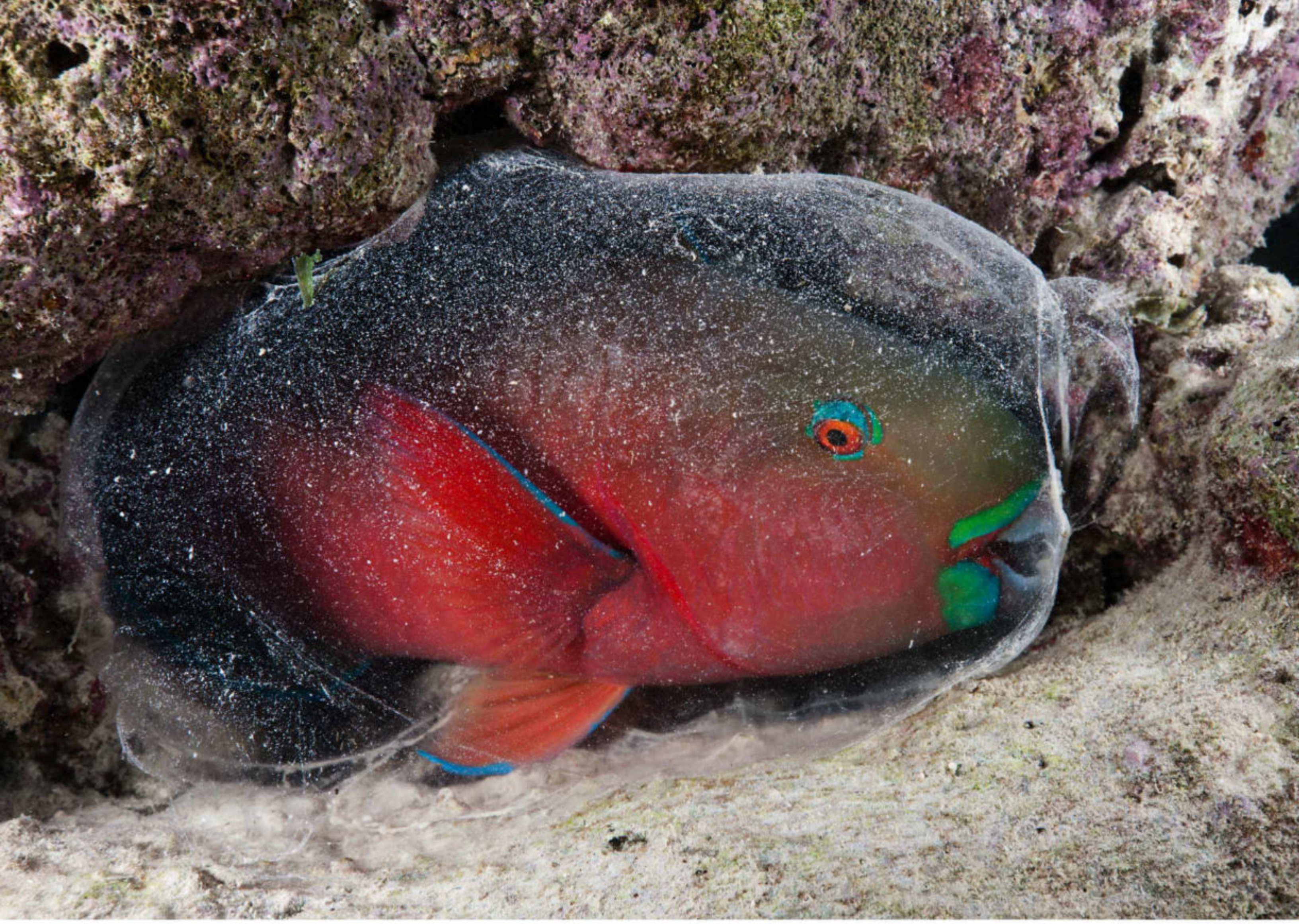
It's impossible to say when life first started using slime, but it happened very early in our evolutionary history. Flemming speculates that the first microbial cells might already have used it, either naturally occurring gels or ones they produced themselves. What we do know is that for billions of years, life on Earth consisted only of microbes with goo.

Microbial slimes are incredibly resilient and have at times dominated the whole planet, covering all habitats in a gooey blanket. Their prominence as a feature of life hasn't gone unnoticed by scientists who try to figure out what aliens might look like.

"We will find life on other planets," says zoologist Dr Arik Kershenbaum at the University of Cambridge. "It will happen soon and it's going to be slime. I think it's extremely likely that there will be planets with microbial life. And I think it's extremely likely that they will live in interacting communities."

Complex multicellular aliens, on the other hand, are a remote possibility and we shouldn't hold our breath. But why look elsewhere when we have the most outlandish creatures right in front of us? No alien could be more bizarre than the snails on our planet, who are blessed with the most versatile goo. Scientists were baffled for a long time how snails manage to crawl, with only one foot? Why, they surf on a wave of slime, of course.

Muscular contractions run like waves across the bottom of the snail. They press on the slime underneath a specific region on their foot, until the slime's inner structure collapses. The mucus liquefies and the snail can glide over this specific spot. Once the wave has passed, pressure is relieved and the framework can rearrange. The slime hardens enough for the snail to push off. But as well as helping the snail to move, the slime also acts



ABOVE When parrotfish want to sleep, they'll blow themselves a mucus bubble to snooze in, which protects them from parasites and predators

as a message board. Snails can read each other's slime trails and find mating partners. Who crawled here? Can I mate with them? Where did they go? So many messages, and they're all written in slime. These bold cries for love can fall on the wrong ears, though. Or a mouth, in the case of the rosy wolfsnail. This carnivorous snail has turned its upper lip into an elongated slime scanner that can sniff out the trails of potential snail prey as well as more familiar tracks of mating partners.

Limpets, however, will use their own slime trails to find their way home. They leave their resting spot – their 'home scar' – to graze the algae off rocks when the tide is high, and follow their own trails back home when the tide goes out, using the slime they left behind as a 'trail of breadcrumbs'.

There is hardly a question in nature that doesn't have an answer in slime, and the tangled web of slime biology is difficult to unravel. Still, if we can fully harness the desirable qualities of slime, such as its superb stickiness, then it could be useful for applications in manufacturing, medicine and technology.

For instance, slime could help us make specialist adhesives. Most glues often fail to work underwater, are toxic, or won't adhere once they've dried out. Many animals, especially in the sea, solved these problems a long time ago. They can stick fast on any wet surface for any length of time and just as easily move on again – or reactivate old glue. The common limpet, for example, is impossible to pry off rocks, while sea stars' tiny feet leave dots of weak glue that can readily be dissolved.

Birgit Lengerer at the University of Innsbruck has studied the sticky slimes of marine creatures, and she certainly sees their potential for technical and medical uses. "With a non-toxic adhesive, we wouldn't have to sew up surgical wounds," she says.

One day we might even wear slime. Scientists around the world are trying to develop new, eco-friendly textiles based on hagfish slime. Even lighter bulletproof vests are seen as an option. And that's not all: the US Navy currently lacks an efficient and safe way to stop other boats in their tracks. Hagfish slime might do the trick and make the sea stay still instead – by turning water into goo. **SF**

by **SUSANNE WEDLICH**
(@SusanneWedlich)
Susanne is a freelance science journalist. Her book, Slime: A Natural History *(£9.99, Granta Books), is available now.*

HOW PROCESSED FOOD HARMS YOUR MOOD

Mental health problems are on the rise. Yet there is growing evidence that the food we eat may be a vital ingredient to help us feel better

by **KIMBERLEY WILSON**

ILLUSTRATION: ADRIÁN ASTORGANO

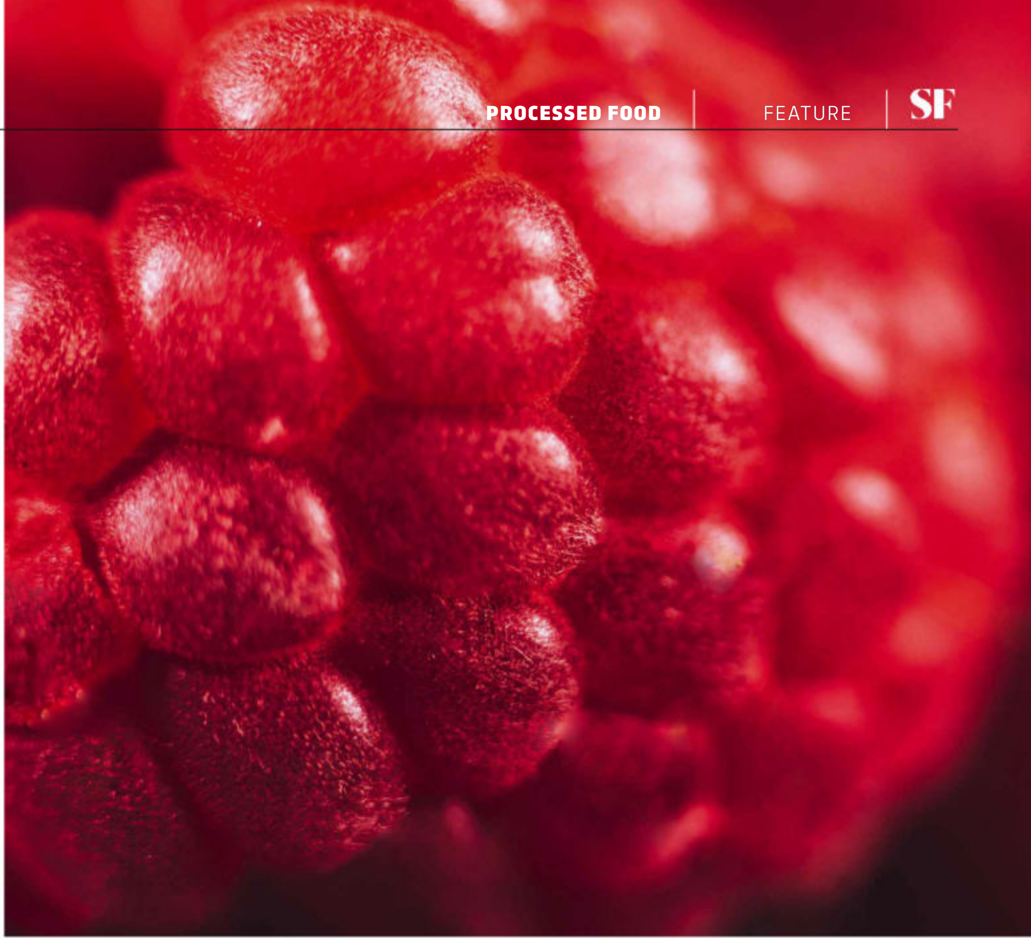
BBC SOUNDS

Listen to Kimberley on the *Made Of Stronger Stuff* podcast, available on BBC Sounds.

The debate on the impact of food on health is something of a contact sport. Food is so deeply imbued with personal and cultural meaning that it can be difficult to remain objective. Food is complex, and increasingly so. While a little over 60 years ago you might have been able to choose from a glass of orange juice, orange cordial or orange soda, you can now also opt for an orange-flavoured energy drink, orange-flavoured vitamin water, orange-flavoured protein water, orange-flavoured water with added magnesium…

Modern food processing has certainly given us more options, but what do we know about the impact of these processed foods on our mental health?

First, let's get clear on the different levels of food processing. A research group recently codified the principles of what constitutes an ultra-processed food (UPF), using something called the NOVA classification. Here, food is divided into one of four groups based on the nature, extent and purpose of food processing. Group 1 includes unprocessed or minimally processed foods, like fresh, squeezed, chilled, frozen or dried fruits and vegetables; pasteurised milk; grains; legumes; and fresh or frozen meat and fish. Group 2 features processed cooking ingredients like sugar, molasses, honey, vegetable oils, butter and lard. Group 3 are called 'processed foods' and include canned or bottled fruits, vegetables and legumes; salted and smoked meats; tinned fish; unpackaged breads; cheeses; and salted or sugared nuts. Group 4 is classed as 'ultra-processed foods', which features those foods made with five or more ingredients, or those ingredients that would not commonly be used in food preparation at home. So we're talking about things like mass-produced breads, biscuits and cakes; breakfast cereals; fizzy drinks; ready-to-heat pizzas, pies, pastries and pastas; instant noodles and soups; and nuggets, sausages and burgers.



It is fair to say that ultra-processed foods are now dietary staples in the UK and US. The UK leads the way in the consumption of UPFs across Europe, with 55 per cent of UK adults' daily calories coming from ultra-processed foods, mostly in the form of baked goods (cakes and biscuits), confectionery, processed meats and soft drinks, and that figure is growing. Americans are slightly ahead of us, with ultra-processed food and drinks making up 57 per cent of their daily calories.

And children are even bigger consumers. A recent 17-year prospective study of the diets of over 9,000 UK children and young people aged 7 to 24 years old found that one in five were consuming over 78 per cent of their daily calories from ultra-processed food and drinks. The main categories in the high-consumption group were fruit-based or fizzy drinks, ready meals and ready-made cakes and biscuits.

CHEAP AND NOT CHEERFUL

But food processing has done much good. Food that lasts longer is cheaper for the consumer. UPFs are convenient to prepare and eat. And, by design, they taste good. So what's the problem?

Though one glass of squash isn't going to kill you, there are reasonable grounds to be concerned about the majority of our diets consisting of these foods. This is because the nature of processing means that brain-healthy nutrients, like vitamins, minerals, antioxidants, essential fats and fibre, are lost. In order to extend shelf life and palatability of UPFs, additional sugar and fats are added, which may have negative consequences for metabolism, blood glucose control and brain health. Finally, and most importantly, the convenience of these foods means that they increasingly push more nutritious but more difficult-to-prepare foods out of our diets. For example, during the same period that US consumption of ultra-processed food and drinks increased from 53.5 to 57 per cent of daily energy intake, consumption of minimally processed foods dropped from 32.7 to 27.4 per cent.

> "THE NATURE OF PROCESSING MEANS THAT NUTRIENTS, LIKE VITAMINS, ESSENTIAL FATS AND FIBRE, ARE LOST"

The problem is, the more our diets are made up of UPFs, the lower our daily nutrient intake. For example, a 2015 Brazilian study assessed the diets of 32,898 individuals over the age of 10 and showed that the consumption of UPFs was inversely correlated to the intake of vitamins B3, B6, B12, D, E, copper, iron, phosphorus, magnesium, selenium and zinc. A more recent Mexican study of 10,000 people found the same thing: the higher the consumption of UPFs, the lower the intake of B vitamins, vitamins C and E, and minerals.

It is this nutritional displacement, I think, that explains why high UPF consumption is linked to worsening brain health, with measurable effects on mood and cognition. A French study →

ABOVE LEFT Iodine, seen here under a microscope, is essential for brain health

ABOVE When eaten raw, berries are full of antioxidants and vitamins, but when heavily processed, some of these nutrients can be lost

LEFT Ultra-processed foods are okay as an occasional treat, but become a problem when they make up a large proportion of the diet

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→ of over 26,000 people, who were assessed at baseline and then followed up around five years later, revealed a significant association between UPF consumption and depression risk. A study of 14,000 Spanish university graduates found the same thing: those individuals who ate the highest amounts of UPFs had the greatest risk of developing depression in the intervening decade.

We are still in the early days of this research, yet the studies seem to show that higher consumption of UPFs is correlated with increased risk of depression. Though there is evidence of a two-way relationship between depression and increased UPF consumption (poorer mood may be both a cause and consequence of poor diet), around a third of the studies in a recent review indicated that greater UPF consumption was a driver of worse mood.

And similar associations have been found in children. A 2021 study of more than 8,000 UK secondary school children was published in the journal *BMJ Nutrition, Prevention & Health*. It spotted a link between higher consumption of fruits and vegetables and improved self-reported mental wellbeing. But that probably means they came from wealthier, less stressed households too, right? Yes, probably, but when the results were adjusted to account for confounding factors such alcohol consumption, smoking status, household income markers, and adverse effects such as bullying, the association held – more fruit and veg was linked to better mental health. But if you need more convincing, we can take a look at the brains of people on Western versus minimally processed diets.

A study published in the journal *BMC Medicine* in 2015 looked at the brains of older people over the course of four years. It found that the healthier the diet, the larger the brain's memory centre, the hippocampus. This is a good thing, as it generally means there are more connections – a feature known as cognitive reserve – which is linked to protection from neurodegeneration.

A separate study published in *Royal Society Open Science* in 2020 showed that negative effects on the brain emerge within days on a Western-style diet, that's high in UPFs. Here, 110 healthy people, who typically ate a nutritious diet, switched to a Western-type diet for just a week. During that week, they were asked to eat two Belgian waffles for breakfast a few times, and to consume a couple of takeaways. Compared to the control

> "THE WESTERN-STYLE DIET GROUP SUFFERED IMPAIRMENTS IN HIPPOCAMPAL-DEPENDENT LEARNING AND MEMORY, ALONG WITH POORER APPETITE CONTROL"

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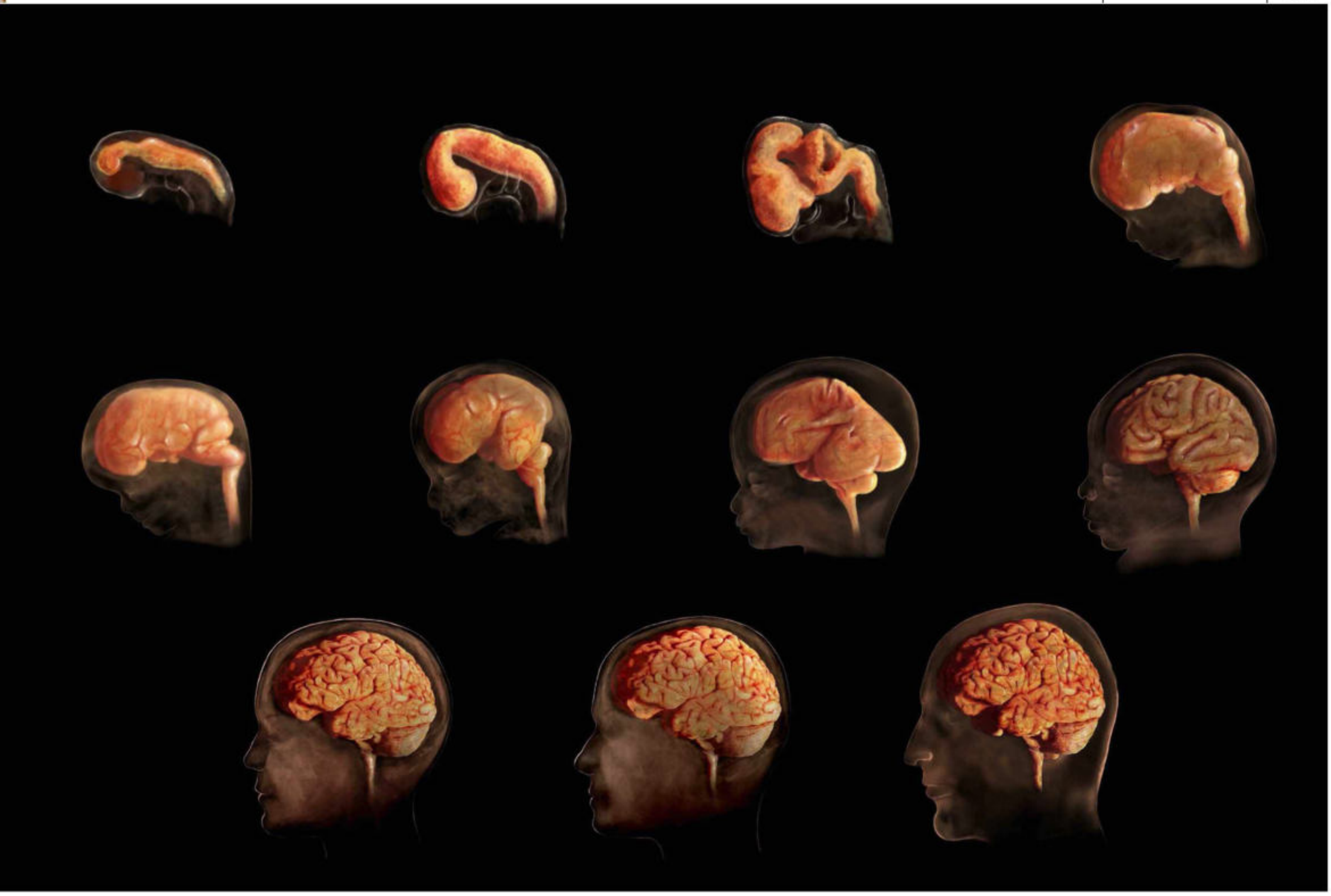
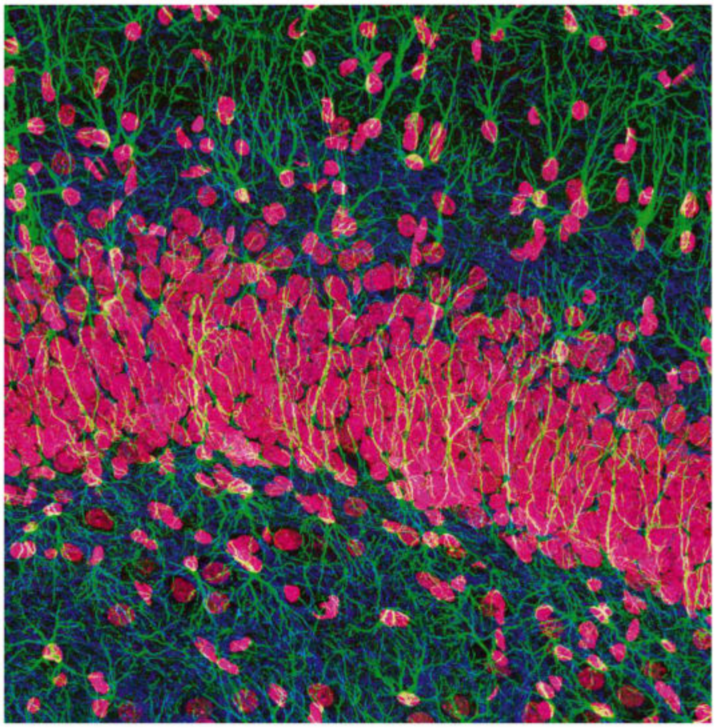


ABOVE LEFT In secondary school children, lower consumption of fruit and veg is linked to worse mental health

ABOVE Brain development throughout our whole lives, from pre-conception to late adulthood, is influenced by the food that we eat. It's never too late to start eating for your brain

RIGHT Hippocampal tissue of the brain, as seen in this microscope image, is responsible for the formation of memories and learning, but can become damaged by a poor diet



group, the Western-style diet group did worse on hippocampal-dependent learning and memory tests, and also had poorer appetite control.

The hippocampus is the part of the brain that is substantially damaged in Alzheimer's disease. The fact that measurable brain damage can be induced by just a few days on a diet that many people eat habitually is concerning.

START RIGHT

However, our ever-growing dependency on UPFs is likely to be having detrimental effects on brain development at the start of life, not just the end of it. According to a review on the links between maternal diet and child health published in *The Lancet* in 2018, the Western diet is typically deficient in magnesium, folate and iodine, which are key nutrients for brain development.

The World Health Organization (WHO) describes iodine deficiency as the single most important preventable cause of brain damage worldwide. At the extreme, →

WHAT TO EAT FOR A HEALTHY, HAPPY BRAIN

Fermented foods
Unpasteurised sauerkraut, kimchi, kefir, blue cheese, live yoghurt, miso, tempeh, fermented pickles and kombucha all help to boost the diversity of beneficial microbes in our gut. While we still have a lot to learn about the effect of the gut microbiome on the brain and mental health, animal studies indicate that the bugs in our guts can influence everything from anxiety to the structure of our brains, and a diverse gut microbiome is supportive of overall health.

Tea, coffee and dark chocolate
These are rich in polyphenols, which can enhance the elasticity of blood vessels, allowing blood to flow more freely. In the gut, polyphenols are converted into phenolic acids, which have a protective effect on brain cells. Tea has been shown to reduce anxiety and improve memory and attention. Caffeine boosts the levels of an enzyme in the brain that has been shown to protect against dementia. And there is evidence that dark chocolate can increase blood flow to the brain and improve working memory and visual function.

Leafy greens
Chard, kale, cabbage, spinach, watercress and rocket are abundant in various nutrients like beta carotene, folate, vitamin K and magnesium, which are involved in the function of the brain and nervous system. Consequently, eating lots of leafy green vegetables is linked to slower brain ageing, better memory and reduced dementia risk.

Raw, unsalted nuts
Nuts like almonds, Brazil nuts, hazelnuts, pistachios and walnuts are valuable sources of polyphenols. When these are digested by our gut microbes, they produce phenolic acids that protect the brain by reducing inflammation and oxidation. They also help to improve how brain cells communicate, and promote formation of new brain cells. Nuts are a good source of vitamin E, which has been consistently linked with better memory function in old age.

Berries
Berries increase the production of a compound that supports the survival of brain cells, with beneficial cognitive outcomes such as improved attention and short-term memory.

Beans and wholegrains
These foods are rich in fibre. When microbes in the gut break down fibre, one of the by-products is a group of compounds called short-chain fatty acids (SCFAs). SCFAs keep the gut barrier healthy and protect the brain from inflammation and oxidative stress. According to the most recent National Diet and Nutrition Survey, only 9 per cent of UK adults aged 19 to 64 consume enough fibre.

Seafood and seaweed
These provide a range of nutrients that are beneficial for supporting the brain's antioxidant capacity. Seaweed and seafood also contain iodine, which is critical for brain development of the baby during pregnancy.

Oily fish
Fish like salmon, mackerel, anchovies, trout, herring and sardines are full of omega-3. Omega-3 fats are irreplaceable when it comes to healthy brain structure and function. Evidence suggests they may be beneficial for those with mild cognitive impairment and depression. We must obtain omega-3 fats through the diet, which can be achieved by eating one or two portions of oily fish per week, or taking a DHA/EPA supplement.

> "A DIETARY PATTERN DOMINATED BY ULTRA-PROCESSED FOODS IS DETRIMENTAL TO OUR HEALTH"

TO HELP REDUCE BLOOD CHOLESTEROL • TO HELP REDUCE BLOOD CHOLESTEROL •
CHOLESTEROL
REDUCING*

LEFT Watch out for health claims on ultra-processed foods

→ iodine deficiency during pregnancy leads to a condition in children called congenital hypothyroidism (previously known as 'cretinism'), which present as significant impairments in physical and mental development. However, less severe iodine deficiency is linked to intellectual and cognitive deficits across populations. Insufficient iodine in the first 14 weeks of pregnancy permanently suppresses a child's IQ. The WHO notes that people who live in areas of iodine deficiency have IQs up to 13.5 points lower than peers in non-deficient areas.

The Avon Longitudinal Study of Parents and Children (ALSPAC) is a study currently following the health of thousands of people born in 1991 and 1992 in the former county of Avon. One research team analysed the cognitive outcomes of the children of 958 women, while also recording the mothers' iodine levels during their first trimester of pregnancy. They found that 67 per cent of the women had mild to moderate iodine deficiency. And these deficiencies were linked to poorer cognition in children. If this has you worried about your levels, seafood and seaweed are good sources of iodine, along with dairy products and eggs.

"Low maternal iodine status was associated with an increased risk of suboptimum scores for verbal IQ at age eight years, and reading accuracy, comprehension, and reading score at age nine years, even after adjustment for many potential confounders," the researchers concluded. "Furthermore, our results suggest a worsening trend in cognitive outcome with decreasing maternal iodine status."

And it's not just iodine that's important for our grey matter. We know that omega-3 fats are essential for brain development, and oily fish is one of the best sources of this nutrient. But most adults in the UK fail to meet the recommendations for oily fish consumption, including pregnant and breastfeeding women. A separate analysis of ALSPAC data found a relationship between maternal fish consumption as measured at 32 weeks' gestation and child IQ. The more fish a mother ate during pregnancy, the higher her child's IQ.

CHANGING TIMES

These associations seem especially meaningful when we note that the Flynn Effect, the observation that global IQ consistently increased over the course of the 20th Century, has been in decline in Western countries such as Norway, Denmark, Germany, Australia and Britain since the 1990s. In fact, one report states that high IQ scores in the UK have been 'decimated' in recent years.

The evidence is accumulating that an overall dietary pattern dominated by ultra-processed foods is detrimental to our physical and mental health. So, what can we do? One solution is to make processed foods healthier, and this is certainly an option that manufacturers like the sound of. Always resourceful, the food industry is now offering us solutions for problems that, arguably, they have created, in the form of 'functional foods'.

Functional foods are a subtype of UPFs that have had some of their nutrients added back in. For example, snack bars and yoghurts with added fibre. The global functional foods market, which is dominated by brands such as Kellogg's, Nestlé, Danone and PepsiCo, is currently estimated to be worth $280bn (£230bn approx) and predicted to grow by 8 per cent by 2030. It's kind of brilliant. They produce, market and sell foods that are nutrient-poor, and then sell us the nutrients back in another product. It's business genius!

In the context of a nutrient-poor diet high in UPFs, functional foods have some benefit, particularly for fussy or picky eaters who might only consume a limited range of foods. However, there are hundreds or probably thousands of nutrients in wholefoods that have not been isolated by food scientists, so simply cannot be added to manufactured foods. A vitamin teabag can't give you what an apple can.

We need a multi-faceted approach that seeks to improve the food environment at every level, from the individual to the whole of society, from pre-conception to old age. And that needs to happen sooner rather than later. The future of our brains depends on it. **SF**

by **KIMBERLEY WILSON**
(@FoodAndPsych)
Kimberley is a psychologist and writer, with a degree in nutrition. Her latest book is Unprocessed: How The Food We Eat Is Fuelling Our Mental Health Crisis *(£22, WH Allen).*

RIO THE PHOTOGRAPHER/BIORESCUE X2 ILLUSTRATION: DANIEL BRIGHT

WHAT COULD THE SCHOOL OF 2050 LOOK LIKE?

GETTY IMAGES

From learning in the metaverse to streamlining administrative tasks, here's our vision of education in 2050

First, we had blackboards and chalk. Then whiteboards and dry-wipe pens, overhead projectors and acetate. Now we have interactive whiteboards. Today's classroom environment has kept pace with new tech, and so too will the classroom of the future.

Undoubtedly, the biggest development we've seen in recent years has been advances in technology. In 2050, net-zero deadlines will be upon us, and green technology will be embedded into the classrooms. Recycling will be second nature and there will be no single-use plastics. Some schools may have gone one step further, with student-grown vertical farms.

Improvements in current technologies will make education more accessible, with additional information available at students' fingertips. And the way we access this information will change. From online learning platforms to more personalised learning experiences, alongside the incorporation of virtual and augmented reality, we may see a shift towards a more interactive method of learning.

By 2050, 3D printers will be a standard appliance. As a learning aid, they will have become essential, allowing teachers more flexibility to explain difficult concepts. Students will be able to physically manipulate objects. The structure of an eye? Easy. Exploring ancient artefacts without risk of damage? No problem.

Adaptive learning systems driven by artificial Intelligence (AI) will have become integrated into the school environment by 2050. Personalised learning experiences will take into account different learning styles and create adaptive assessments that adjust in real-time based on performance. AI may also be used to analyse pupils' work, even predicting future performance, helping teachers understand which students need more guidance on a concept before they fall behind. Students will be able to get immediate feedback, with suggested areas for improvement and more personalised tutoring, tailored to a student's strengths and weaknesses. This isn't a new concept – Intelligent Tutoring Systems (ITS) have been proposed for decades – but AI will make it considerably easier.

But with AI having become more widely accessible – like the recently launched ChatGPT that can generate sophisticated paragraphs of writing from prompts – so too will new plagiarism detection software. Sorry, students.

HOW THE INTERNET WILL CHANGE SCHOOLS

- Homework will be completed and submitted remotely, with students and parents receiving notifications of performance.
- The Internet of Things will allow automation of the classroom environment.
- VR and the Metaverse will offer immersive learning experiences, along with opportunities for meet-ups with students round the world.

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Q&A

YOUR QUESTIONS ANSWERED

- … COULD DINOSAURS HAVE HAD SYMBIOTIC RELATIONSHIPS WITH OTHER ANIMALS?
- … WHAT'S THE BEST WAY TO DRY CLOTHES INDOORS?
- … WHY DO COMPUTERS AND CONSOLES NEED TO RESTART TO INSTALL UPDATES?
- … HOW DOES DENDROCHRONOLOGY WORK?
- … ARE THERE REALLY DINOSAURS IN FOSSIL FUELS?
- … HOW DO ROBOT VACUUM CLEANERS NAVIGATE?
- … WHY DOES BAD NEWS MAKE ME FEEL SICK?
- … WHAT GIVES CLOUDS THEIR SHAPE?
- … DO WEIGHTED BLANKETS REALLY WORK FOR ANXIETY AND INSOMNIA?
- … HOW DO ROCKS STAY ON THE SURFACE OF DIMORPHOS?

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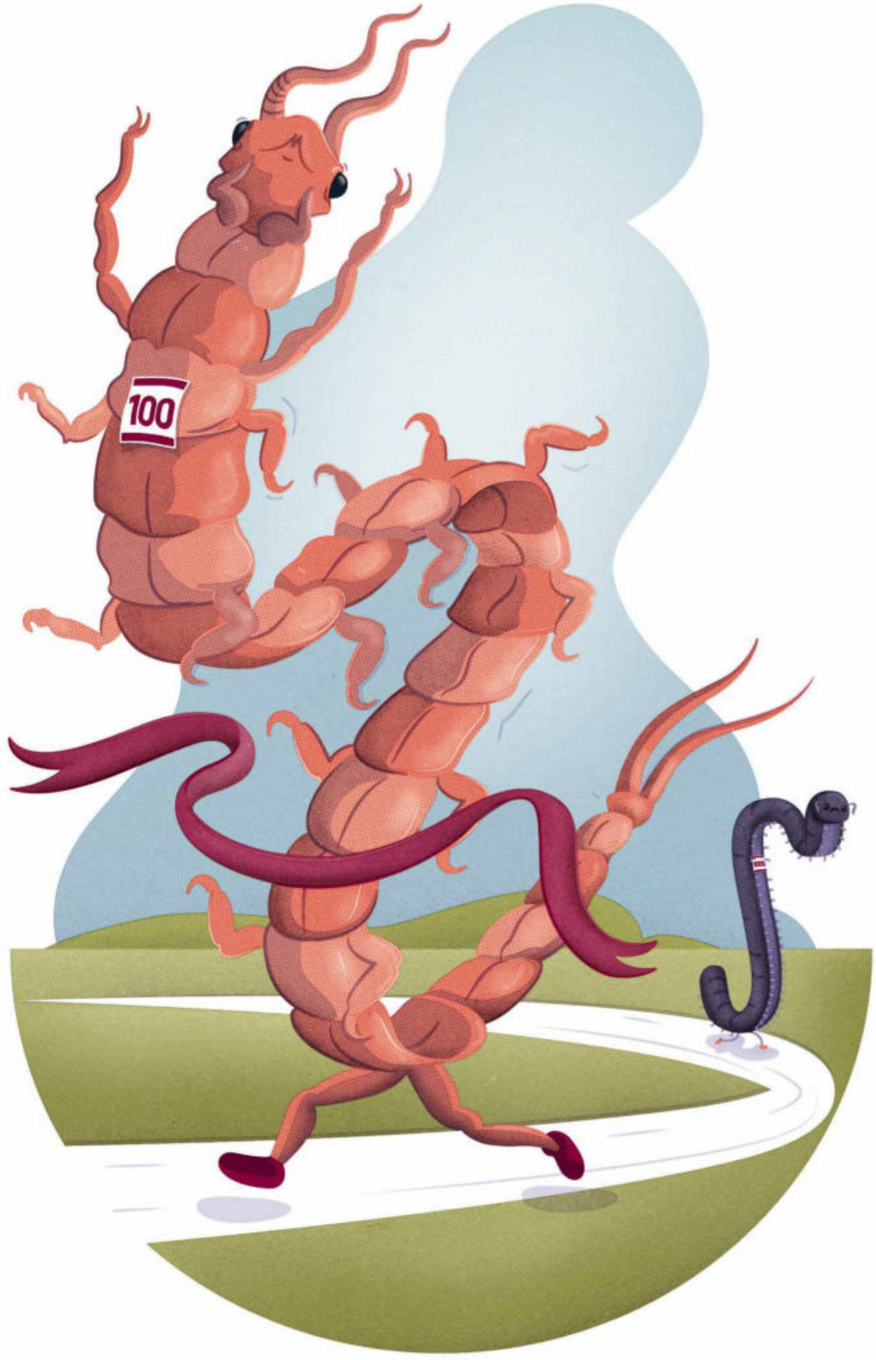


ILLUSTRATION: DANIEL BRIGHT

CHARLOTTE EDWARDS, CHELTENHAM

WHICH WOULD WIN IN A RACE, A CENTIPEDE OR A MILLIPEDE?

Centipedes are much faster. Precise figures are hard to come by, but common centipede species run at comparable speeds to a spider, whereas millipedes move more at the pace of an ant. The reason for this has nothing to do with their different numbers of legs – the leggiest centipede species have 384 legs, which is more than a typical garden millipede. But almost all centipedes are hunters and have evolved legs that splay out sideways from their body, which allows a rapid rowing motion as they chase prey. Millipedes have shorter legs tucked underneath their bodies to give them better traction as they push their way through soil and leaf litter. ***LV***

NATURE'S WEIRDEST CREATURES...

HARPY EAGLE

The harpy eagle is one of the largest and most powerful raptors on earth. Native to the rainforests of Central and South America, it is named after the harpies of Greek mythology; malevolent wind spirits with the face of a woman and the body of a vulture. The harpy eagle is an apex predator. Its broad and relatively short wings enable it to fly almost straight up, so it can navigate the understory of the forest, and attack from below as well as above. Monkeys, sloths and opossums beware; the harpy eagle can snatch prey weighing up to 8kg. Its curved black talons, which can grow up to 13cm long, can exert over 50kg of pressure, so it kills its victims by crushing them.

Cloaked in demure shades of grey, the harpy eagle is crowned with a double crest of slate-coloured feathers, which fan out whenever the bird feels threatened. A smaller ring of lighter feathers around the face creates a disc that is thought to help focus soundwaves, while the bird's eyesight is impeccable: it can spot an object less than 2cm in size from a distance of 200 metres. The harpy eagle is bold, beautiful, and sadly under threat – its conservation status is classified as 'vulnerable' with logging, poaching and habitat destruction largely to blame. ***HP***

FREDDIE WILLIAMS, LONDON

COULD DINOSAURS HAVE HAD SYMBIOTIC RELATIONSHIPS WITH OTHER ANIMALS?

Many plants and animals in nature live together in long-term interaction. This is called symbiosis. It might be mutually beneficial, or one of the organisms may be a parasite on the other. There are many examples in nature today, from the algae that live inside corals, to fungi that grow on the roots of plants (mutualistic relationships), to many types of parasites such as worms and bugs preying on their hosts. There is evidence that dinosaurs like *Tyrannosaurus rex* were affected by parasites, as some fossil bones are pitted with lesions that resemble those caused by protozoan parasites in modern-day birds. Evidence for mutualistic symbiosis between dinosaurs and other species is not so clear, as such evidence is unlikely to fossilise. But just like birds that help pick the teeth of crocodiles today, it is easy to imagine that dinosaurs must have had similar relationships, perhaps with their bird descendants, in the past. ***SB***

BETTY DIXON, STOKE-ON-TRENT

WHY DO COMPUTERS AND CONSOLES NEED TO RESTART TO INSTALL UPDATES?

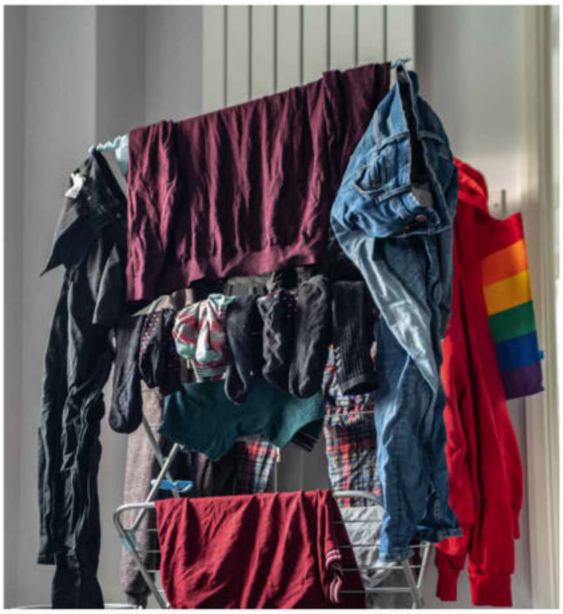
Software comprises lots of files and programs all interacting. When a computer is running software, it loads much of the program into its memory. If we managed to update that same software on the hard disk or SSD, then the program may panic as everything will be different – it won't be able to find the files that were there a moment ago. The version in memory will not be compatible with the version on the hard disk or SSD. Lots of errors will be thrown and your computer may crash. To prevent this, operating systems usually insist that when major updates are needed, we shut down the software being updated, then restart with the new software installed. ***PB***

ERIC PEARSON, VIA EMAIL

WHAT IS THE BEST WAY TO DRY CLOTHES INDOORS?

The ideal way to dry wet laundry is to hang it outside on a warm, sunny day, but that's not always possible. When drying clothes indoors, three main factors determine drying time: temperature, humidity and airflow. The water molecules trapped in the fabric's fibres must evaporate by turning into water vapour. This happens as water molecules jostling within the fabric gain enough energy to turn into a gas, a process that is accelerated if the material is warmer. At the same time, water molecules in the air randomly condense onto the fabric. So, the drier the air, the higher the ratio of evaporation to condensation, and the faster clothes will dry. Warmer air holds more water, so higher temperatures reduce the relative humidity, which help clothes dry faster. A flow of fresh air carries moisture-laden air away from the drying clothes, minimising condensation back onto the fabric. So, when drying clothes indoors, pick a warm, dry room with good ventilation.

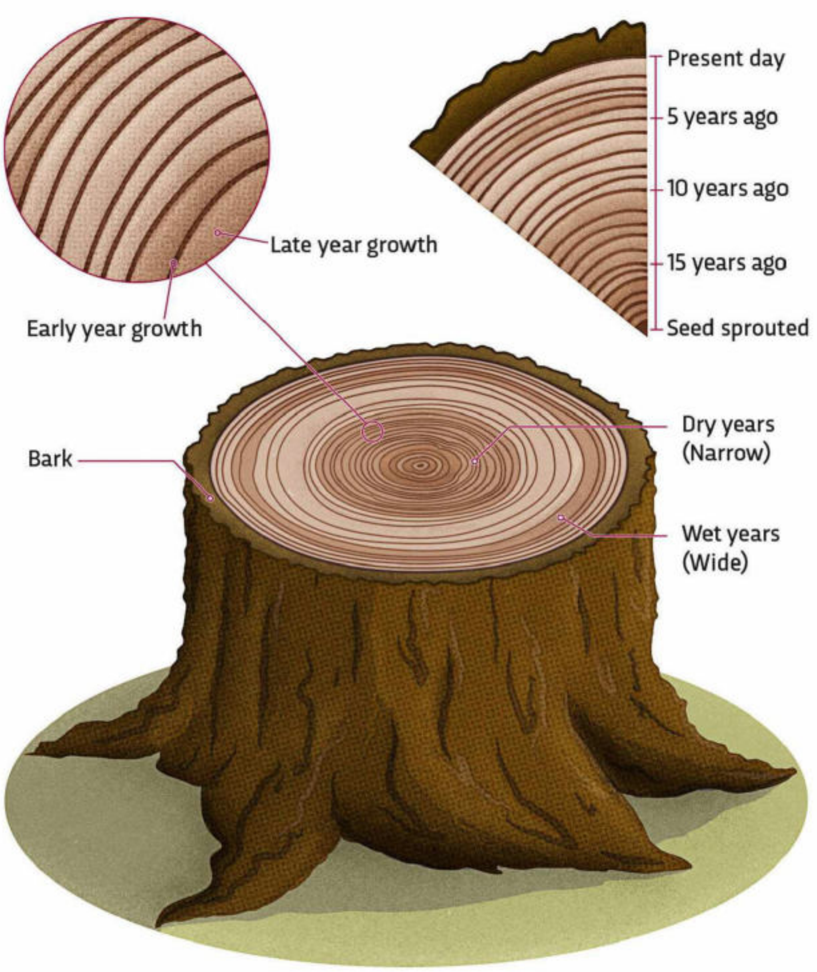
Of course, there are also some technological solutions that can speed up this process. Heated clothes airers accelerate evaporation via hot bars, while tumble dryers use a flow of warm air to heat the clothes and carry moisture away. Airers are generally cheaper to buy and run, but take longer, so for large loads, a tumble dryer may work out cheaper. Traditional tumble dryers vent the steam they produce, while modern condenser dryers collect the evaporated moisture in a tank. Heat pump condensers are the most efficient because they recirculate warm air in the machine; but they're also the most expensive to buy. Drying pods are a relatively new invention; they blow hot air through clothes hanging underneath a cover. They tend to dry clothes faster than heated airers but are more expensive to buy and run. ***CA***



GETTY IMAGES X2, ALAMY ILLUSTRATION: DANIEL BRIGHT

HELEN STEVENSON, VIA EMAIL

HOW DOES DENDROCHRONOLOGY WORK?



Dendrochronology is a technique that involves calculating the age of a tree, or a piece of wood, by counting growth rings. As well as growing upwards, trees grow outwards each year by adding new woody tissue just underneath the bark, in an area known as the vascular cambium. In the spring, trees produce large, thin-walled cells under the bark, but as growth slows towards the end of the summer, they add denser, thicker-walled 'latewood' cells that appear darker in colour, leaving visible rings in the trunk that mark each year of growth.

Dendrochronology has a wide range of applications, including dating archaeological remains and calibrating radiocarbon dating. As the width of each ring depends on how much new tissue was added during the growth season, which is influenced by the climate and environmental conditions that year, tree rings can reveal information about past climatic changes. However, like all techniques, dendrochronology has limitations.

First, it requires a full cross-section of a tree, right up to the bark, which is not always present in trimmed timber samples. Additionally, damage to the tree (such as removing the bark) can deform tree rings as the plant grows over the scar. Some trees can be more reliably dated than others. Oak trees, for example, reliably produce a single ring each year, whereas alder, pine and birch have more erratic growth cycles and may skip a ring in some years, or double-up in others. ***CA***

IAN MCCOY, VIA EMAIL

ARE THERE REALLY DINOSAURS IN FOSSIL FUEL?

Most oil reserves were formed between 65 and 252 million years ago. While this does overlap with the 'dinosaur times', oil is a marine sediment made of the remains of algae and plankton. Skeletons of prehistoric reptiles such as plesiosaurs and ichthyosaurs (neither of which count as dinosaurs) have been found in the same geological layers as oil and they may have contaminated the oil deposit. But to say that oil is made from dinosaurs is like saying that bread is made from insects, just because the odd one occasionally falls into a flour mill. Oil sediments formed in shallow seas that were teeming with life near the surface but stagnant and dead on the seabed. As dead plankton and microorganisms rained down, they buried the ones below them faster than they could decay. This trapped the organic matter in an oxygen-deprived layer that sank lower and lower as it was compressed from above. After 100 million years of this, the bottom layers were under several kilometres of clay and sand, and the heat and pressure at these depths converted the organic material into oil.

In contrast, a five-tonne plesiosaur falling dead to the seafloor would be very unlikely to remain undisturbed for long enough to be safely buried. Instead, it would be a temporary oasis for fish, crustaceans and worms that would quickly strip away the organic parts. We see this happening today when whale corpses fall to the seabed.

Coal is a much better place to find fossils; in fact, many plant and animal remains have been found preserved in coal seams. But coal deposits date from the Carboniferous era (359 to 299 million years ago), about 57 million years before the earliest dinosaurs. And even those animal fossils are embedded in, rather than contributing to, the coal deposit itself. ***LV***

CROWDSCIENCE

Every week on BBC World Service, *CrowdScience* answers listeners' questions on life, Earth and the Universe. Tune in every Friday evening on BBC World Service, or catch up online at **bbcworldservice.com/crowdscience**

WHAT GIVES CLOUDS THEIR SHAPE?

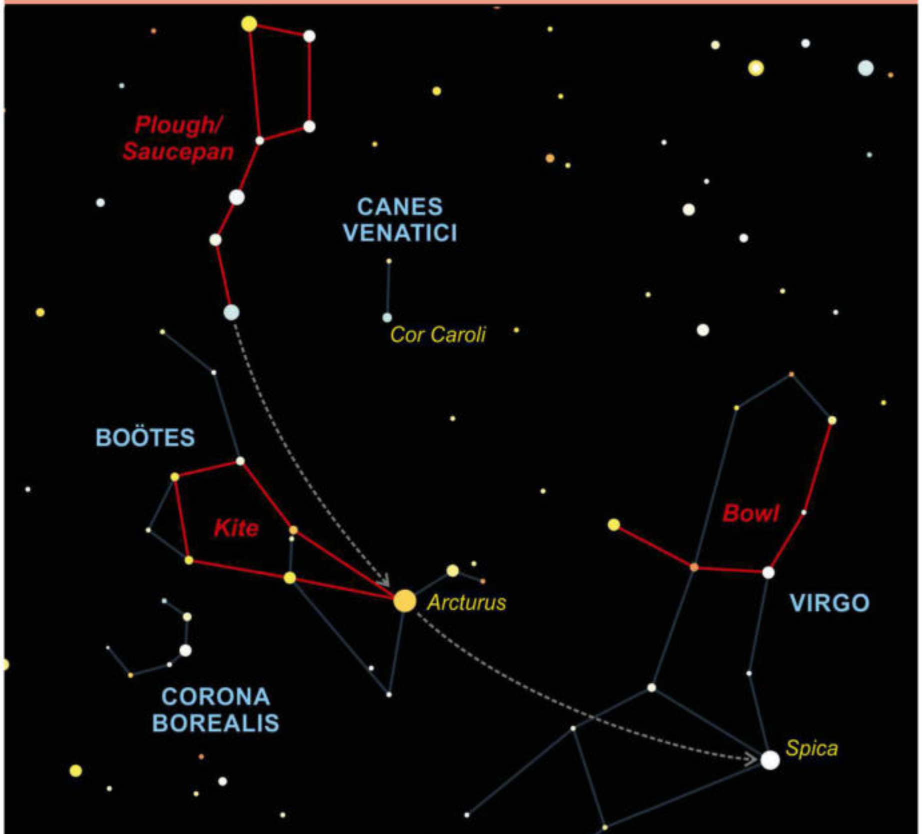
If you've ever tried to make out faces or animals in the contours of the clouds, you might have wondered why they come in such a variety of shapes. Moisture is always present in the air as water vapour, but when it condenses into liquid droplets or solid ice particles, these particles scatter light, making them visible as clouds.

The shape of a cloud is determined by air temperature, density and movement. Differences in temperature and density prevent water-laden air from mixing with the surrounding air, giving clouds a distinct shape and creating crisp edges. Air movement pulls clouds into different formations.

Although no two clouds are exactly the same, they can be grouped into categories. Cumulus clouds are puffy and cotton-like, forming low in the atmosphere. When water vapour condenses into liquid water, it releases some heat, and if atmospheric conditions are unstable, this heat is enough to give cumulus clouds buoyancy, causing them to rise and build into cumulonimbus clouds. These large, dark clouds topped with billowing turrets are formed by rapid updraughts of air and are often accompanied by thunderstorms. In contrast, stratus clouds form as wide layers when a large region of air rises. Finally, cirrus are delicate, wispy clouds formed of ice crystals at high altitudes. As they gradually sink, they pass through air currents that push and pull them in different directions, forming long, feathery wisps of cloud. *CA*

GETTY IMAGES X2, ILLUSTRATIONS: DANIEL BRIGHT, PETE LAWRENCE

ASTRONOMY FOR BEGINNERS



HOW TO STAR HOP

WHEN: SPRING

Star hopping is a tried-and-trusted technique used to locate things in the night sky. It relies on identifying recognisable shapes formed in the stars and using those as directional guides to your final target.

There's an excellent example high in the northeast as darkness falls at this time of year. The pattern is the Plough or if you prefer, the Saucepan. Formed from seven stars of medium brightness, it is probably easier to recognise as a saucepan. As darkness falls, the Saucepan appears to balance precariously on the tip of its handle.

The curved handle approximates a portion of a circle. Imagine where the centre of the circle would be, applying some artistic licence as the star we're looking for isn't precisely at the circle's centre, but is the brightest in the vicinity. The star is Cor Caroli, part of the small constellation of Canes Venatici, the Hunting Dogs.

Return to the Saucepan, extending the handle's arc away from the pan, for a distance similar to the length of the Saucepan. This brings you to the orange-coloured Arcturus, the brightest star in Boötes, the Herdsman. The Canes Venatici hunting dogs belong to Boötes, a constellation that resembles a giant kite, with Arcturus at the pointed end. The kite is as tall as the Saucepan is long. If you can identify it, look for the distinctive semi-circle of stars below it, representing Corona Borealis, the Northern Crown.

Keep the Saucepan's handle arc going through Arcturus to eventually arrive at bright white Spica, the brightest star in Virgo, the Virgin; you may have to wait for Spica to rise to be able to see it. There's a catchy saying to remember how to find Arcturus and Spica, which goes, 'follow the arc to Arcturus and speed on to Spica'. Virgo isn't so easy to identify, but it does have one distinctive large pattern known as the Bowl. ***PL***

SALLY RIVERS, NORWICH

HOW DO ROBOT VACUUM CLEANERS NAVIGATE?

Early robot vacuum cleaners were quite simple: they randomly bumped around a room, changing course whenever they encountered an object so that eventually their random pattern of vacuuming would cover the whole floor. Robot vacuum cleaners today are packed full of sensors and computers and are considerably cleverer.

LiDAR, also used by autonomous vehicles, is often used to detect walls and obstacles by bouncing invisible beams of light off them. Some robots use VSLAM (visual simultaneous localisation and mapping) – a way of processing images from a camera to understand the surroundings of the robot and its location. The robots might also use ultrasonic ToF (time of flight) sensors, which work in a similar way to the echolocation of a bat, to avoid obstacles or detect if the floor is hard, soft or missing. They have accelerometers to identify motion and sensors to detect if their wheels are tangled up. Finally, suction sensors detect if their airways are blocked and the dust bucket is full.

All this information is used by AI software to determine the location of the robot and help it build a map of your rooms and furniture as it cleans. The robots are designed to clean every square inch of the floor and so they attempt to plan the most efficient route while remembering the way back to the charging station. However, they cannot always see everything (and we may move things as they clean) so the coverage is not always perfect. Navigation becomes more difficult if their sensors become partially blocked – a robot under your sofa may be largely blind and can become quite lost!

The cleverest robot vacuum cleaners show you their maps of your home and allow you to tell them where they should concentrate and where they should avoid. The stairs are still beyond them… but Dyson filed a patent for a stair-climbing cleaning robot in 2020, so watch this space! ***PB***

MYTHBUSTERS

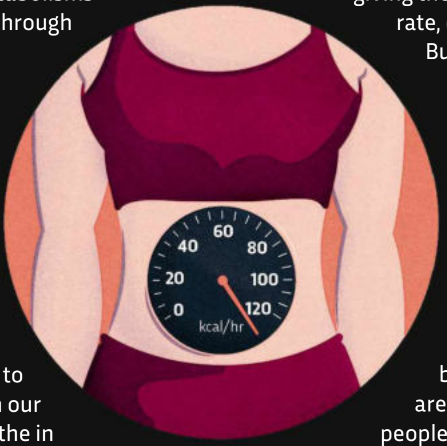
SKINNY PEOPLE HAVE FASTER METABOLISMS

Most of us have a friend that can eat whatever they want, whenever they want, and still somehow stay slim. They may say they've been blessed with a fast metabolism, but is that really the case?

The metabolism is the process by which our bodies turns food and drink into the energy we need for life. Often, scientists talk about metabolism in the context of the body's energy use over the course of a day, which is called the metabolic rate. The more energy expended, the higher the metabolic rate. It follows, then, that people with fast metabolisms are those that burn through a lot of energy in one day.

The majority of the energy we get from food is used by the body simply to keep us alive. Living is costly: we need energy to keep us warm in winter, to fight off invading pathogens, to pump blood through our arteries, and to breathe in and out. The energy requirements of these fundamental tasks are often referred to as our basal metabolic rate (BMR), and BMR accounts for 60 to 80 per cent of our total energy expenditure in a given day. For most of us, physical activity accounts for 15 to 30 per cent of our daily energy expenditure. A small percentage of energy is put towards energy harvesting itself, powering our digestive system.

One of the biggest components of BMR is the energy demands of muscle cells. Compared to other cell types, muscles are much more active, needing energy to contract and relax, and to repair themselves against daily wear and tear. The more muscle a person has, the higher their BMR.



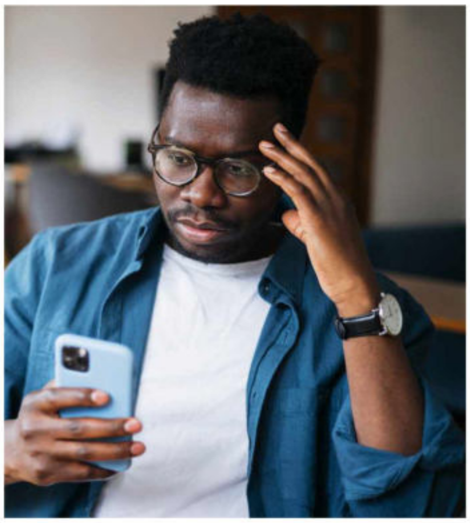
This brings us back to our skinny friend who can eat whatever their heart desires: they will generally have less muscle mass, and so their BMR will be lower, giving them a slower metabolism. People who weigh more will have more cells of all types, including muscle cells, making their body's daily energy demands higher and giving them a higher metabolic rate, or fast metabolism.

But weight on its own isn't a reliable indicator for a metabolic rate, because two people who both weigh the same can have vastly different muscle mass. Physical appearance is no better metric – there are some visibly skinny people who will have more muscle mass and very little body fat, like Olympic medallists and professional dancers, and thus have a higher BMR overall.

So why is our friend so slim? It could be inherited – genetics has a small impact on BMR – or they could be leading an active lifestyle. An unbalanced diet could be contributing to their weight loss, or they may be eating less when they're away from your company. Whatever the reason, you're now armed with a retort when they say, "I'm so lucky to have a fast metabolism!" ***AA***

AMELIA MONTGOMERY, VIA EMAIL

WHY DOES BAD NEWS MAKE ME FEEL PHYSICALLY SICK?



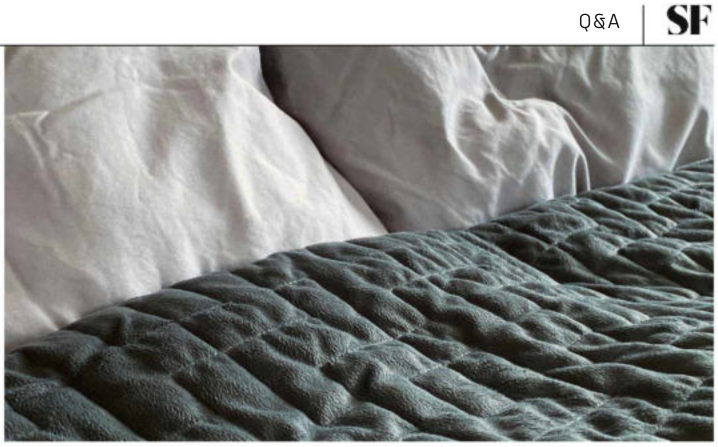
When you discover something bad has happened, it can trigger your body's 'fight or flight' response. It's governed by what's known as the sympathetic nervous system, which sends commands from your spinal cord to your body's major organs, including your heart and intestines, gearing you up to either fight or flee when faced with danger.

A key part of the fight or flight response is to shut down digestion so that blood flow and energy can be sent to your limb muscles instead. In some people, this sudden effect on digestion can manifest as nausea, vomiting or diarrhoea. In short, the bad news has prompted you to feel threatened and your body has triggered your survival mode.

The sympathetic nervous system is in constant opposition with the parasympathetic nervous system, which is more active when we're relaxed. It sends its own messages to your body, including to encourage digestion. So anything you can do to boost your parasympathetic nervous system activity ought to help you overcome those feelings of sickness. This is easier said than done, but basic steps include deliberately slowing down your breathing. Consider writing a list of those aspects of the situation that are out of your control, and those that you can do something about. For those things you have some influence over, try to come up with some achievable plans to make the situation better. Over time, distraction, exercise and meditation can help you relax and cope with stress. Don't be afraid to ask for help from friends and family – or seek professional support if the feelings of nausea won't go away. ***CJ***

PAUL MOSS, EXMOUTH

DO WEIGHTED BLANKETS REALLY WORK FOR ANXIETY AND INSOMNIA?



A weighted blanket contains glass beads, plastic pellets, ball bearings, or other materials that add to the blanket's overall weight. They have increased in popularity in recent years, and many companies claim that the extra pressure helps to reduce anxiety and stimulates sleep.

Many people with anxiety and/or depression find themselves trapped in a vicious cycle. Anxiety and depression can negatively affect sleep, and the lack of sleep worsens the anxiety and depression. So addressing the underlying issue with sleep is key to helping with these conditions. However, the evidence for weighted blankets is sparse, given the difficulty of conducting randomised control trials for their use.

A systematic review in 2020 published in the *American Journal Of Occupational Therapy* found that using a weighted blanket improved people's ability to fall asleep, to sleep through the whole night, and to relax during the day. Using a weighted blanket improved the morning and evening daily routine, including preparing to sleep and waking up in the morning. However, the authors concluded that while weighted blankets may be an appropriate therapeutic tool in reducing anxiety, there is not enough evidence to suggest they are helpful with insomnia.

If you do opt for one, it is typically recommended that you buy one that weighs approximately 10 per cent of your body weight. You want to be careful not to get one that feels too hot, as sleeping in a cooler environment has been shown to help with insomnia. It's also worth thinking more broadly about the environmental factors impacting on your sleep, such as darkness, the influence of screens, and background noise. ***NM***

QUESTION OF THE MONTH

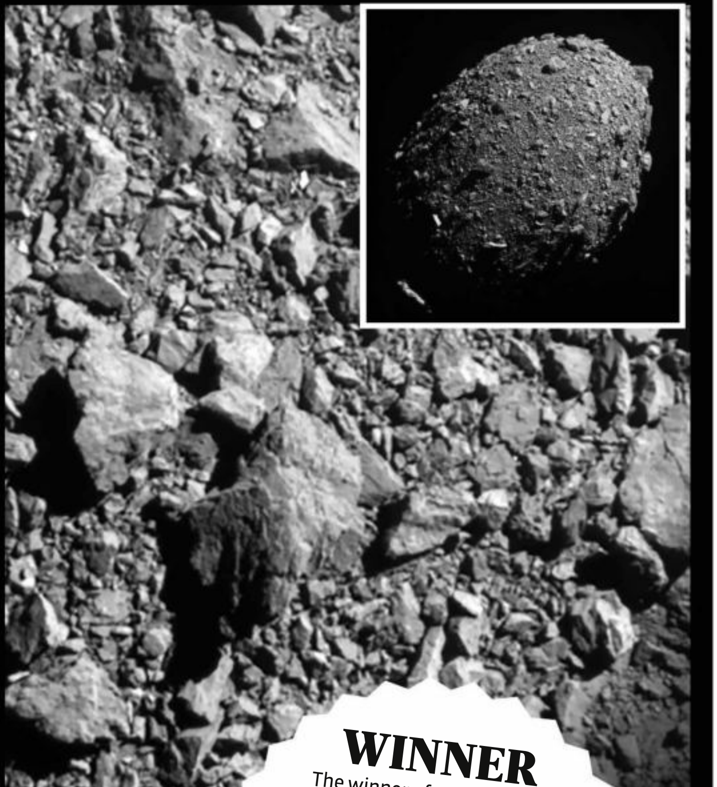
ROGER JORDAN, VIA EMAIL

HOW DO THE ROCKS STAY ON THE SURFACE OF DIMORPHOS?

Many small asteroids, such as Dimorphos, Ryugu and Bennu, have quite low densities compared to moons or terrestrial planets. Known as 'rubble-pile' asteroids, they appear to be composed of loose conglomerations of rocks, small grains and dust, and are not 'solid' at all. Planetary scientists believe that rubble-pile asteroids are formed by material coalescing after the destruction of larger asteroids.

The Japanese spacecraft Hayabusa2 visited asteroid Ryugu in 2018 and revealed that about 50 per cent of its volume is empty space! Meanwhile, measurements have revealed that Bennu has a density only slightly greater than that of water. It is likely that Bennu has hollow cavities in its interior, some of which are probably filled with water. NASA's OSIRIS-REx probe, which collected a sample from Bennu in 2020, would almost certainly have sunk into Bennu's surface had it not fired its rockets on contact.

Just like other celestial bodies, it is gravity that keeps these asteroids together – as long as the centrifugal force due to their rotation is not strong enough to overcome gravity. Research has shown that, for many asteroids, 'cohesive' and 'adhesive' forces – the tendency of materials to attract each other and 'stick together'– are also required to prevent rotation from tearing these asteroids apart. In fact, the ratio of the gravitational to centrifugal forces on a rubble-pile asteroid determines not only the maximum size of boulders on its surface, but also the minimum mass at which the asteroid can remain intact. So a boulder on the surface of Dimorphos is easily held there by gravity because the asteroid's rotation is not sufficient to overcome gravity and throw it off into space. ***AG***



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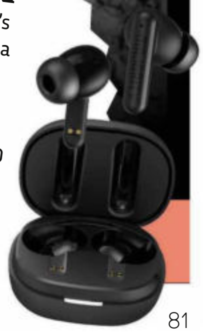


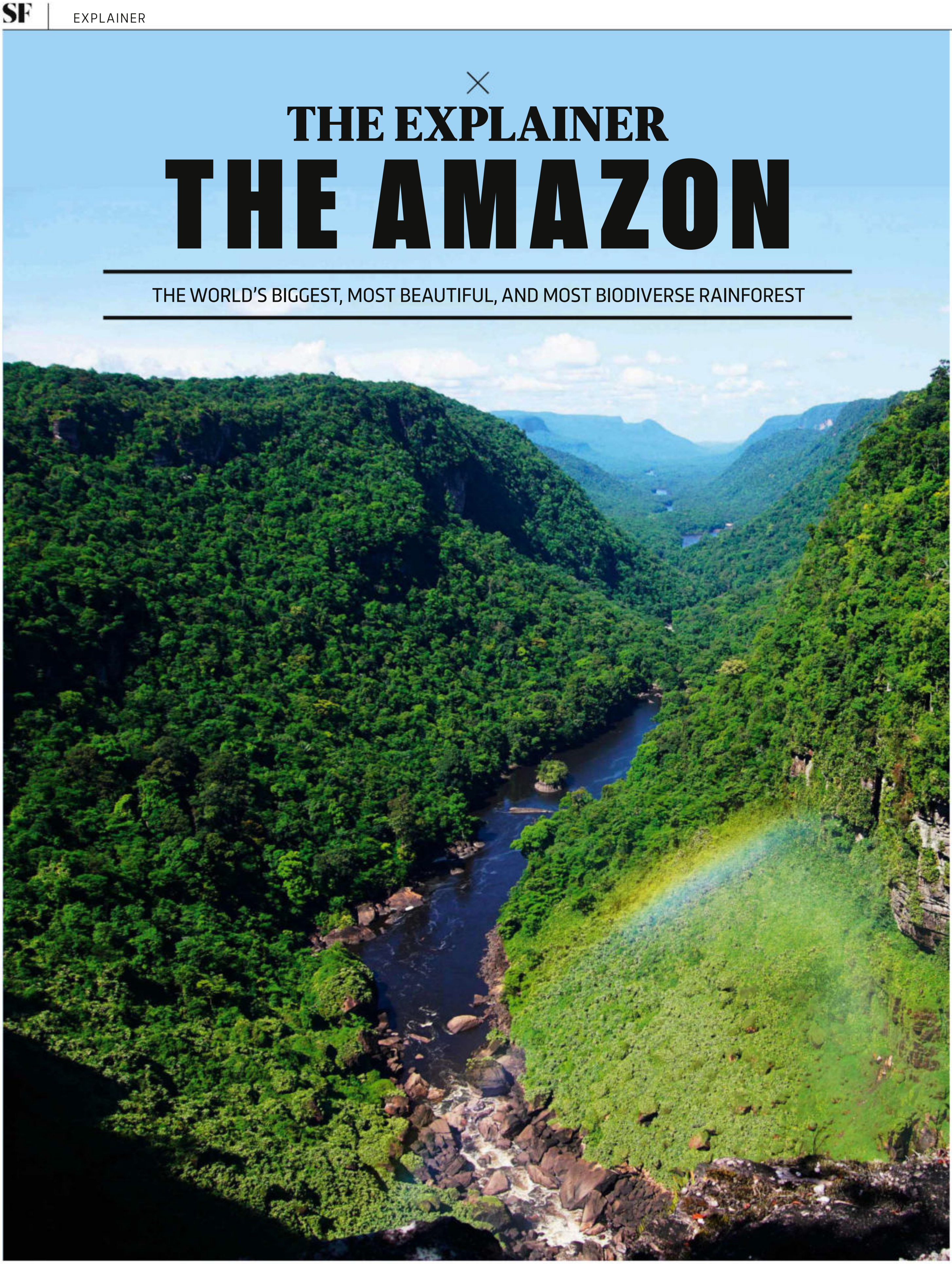
EMAIL YOUR QUESTIONS TO **QUESTIONS@SCIENCEFOCUS.COM**

GETTY IMAGES, ALAMY, NASA/JPL X2 ILLUSTRATION: DANIEL BRIGHT

THE EXPLAINER

THE AMAZON

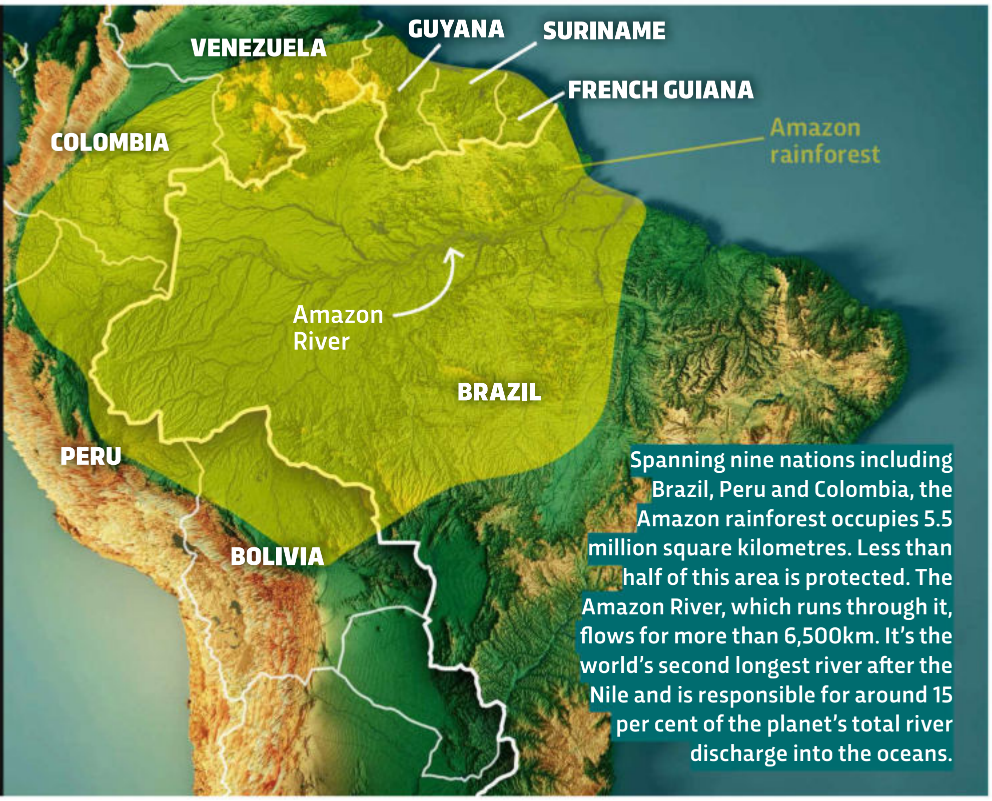
THE WORLD'S BIGGEST, MOST BEAUTIFUL, AND MOST BIODIVERSE RAINFOREST



GETTY IMAGES X3

WHAT IS IT?

The Amazon rainforest is the largest remaining tropical rainforest in the world. It's also the most biodiverse. One in ten of all known species are found here, including many that are endangered and found nowhere else. It's big and it's beautiful, and it's vitally important, not least because it stores vast amounts of carbon, influences rainfall patterns across South America, and affects climate on a much broader scale. In the last 40 years, around a fifth of the rainforest has been felled or burned to make way for cattle ranches and other activities. Now scientists fear it's on the verge of irreparable damage. We lose it at our peril. We need to act now to save one of the world's last true wonders.



Spanning nine nations including Brazil, Peru and Colombia, the Amazon rainforest occupies 5.5 million square kilometres. Less than half of this area is protected. The Amazon River, which runs through it, flows for more than 6,500km. It's the world's second longest river after the Nile and is responsible for around 15 per cent of the planet's total river discharge into the oceans.

WHO LIVES THERE?

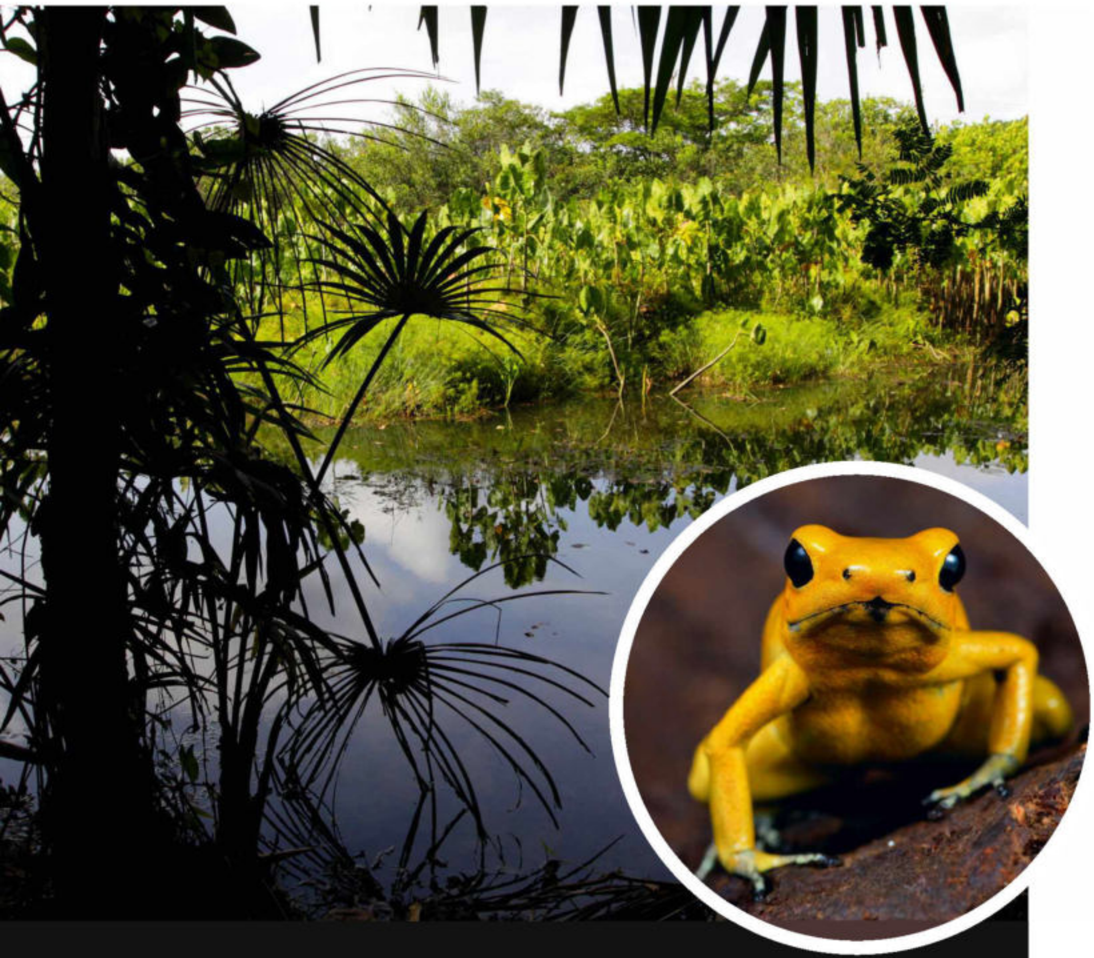
People have been living in the Amazon for at least 10,000 years. Ancient settlers cultivated native trees such as the Brazil nut, maripa palm, and cocoa tree, and in time this influenced the rainforest's makeup. The southwestern section, for example, is rich in these species.

When the first Europeans arrived in South America in the late 15th Century, there were about 6.8 million indigenous people living there. The colonists carried infectious diseases, such as malaria and influenza, that killed millions of Amazonians. Thousands more were enslaved or displaced.

Today, around 30 million people live in the Amazon region, of which 2.7 million are indigenous, representing more than 350 different ethnic groups. Most live in indigenous reserves known as 'resguardos' where their lifestyles incorporate a mix of traditional and Western elements. Around 60 tribes, however, live in voluntary isolation, and stick largely to the tried and tested ways of their ancestors.

> "Colonists carried infectious diseases, such as malaria and influenza, that killed millions of Amazonians"

> “The Amazon rainforest is sometimes called the ‘lungs of the Earth’ because it ‘breathes in’ carbon dioxide and ‘exhales’ oxygen on a massive scale”



HOW OLD IS THE AMAZON?

No one knows for sure. Some think that the Amazon rainforest began to form during the Eocene, around 55 million years ago, after temperatures dipped and the Atlantic Ocean widened enough to provide the region with a warm, moist climate.

Some experts think it happened later, around 15 million years ago, after the South American and Nazca tectonic plates smashed together to form the Andes, creating a massive freshwater lake that covered the Amazon basin. Several ice ages later, and water started to flow from the Andes into the ocean. The Amazon River was born. Sediments from the mountains washed into the Amazon basin, creating the soils needed for the rainforest to grow.

Others think it is more recent still. One study suggests that up to a fifth of the Amazon basin could have been grassland until a natural shift to a wetter climate around 2,000 years ago prompted the growth of more trees.

GETTY IMAGES X3, ALAMY

HOW MUCH BIODIVERSITY IS THERE IN THE AMAZON?

The Amazon is home to at least 10 per cent of the world’s known biodiversity. From hummingbirds to hoatzins, there are more than 1,000 different species of birds. There are over 500 different reptile species, including black caiman and green anacondas, and more than 400 species of amphibians, including the giant cane toad and the notoriously toxic poison dart frog.

The region is a refuge for more than 300 species of mammals, including giant otters, ocelots and sloths. It is also one of the last refuges for jaguars and pink river dolphins. The Amazon River contains around 3,000 freshwater fish species, which is more than any other river system. One in five fish species live here.

There are an estimated 2.5 million insect species. And on just one tree, there can be more types of ant than there are in some countries. Let’s not forget the plant life either. The rainforest contains around 80,000 plant species, including 390 billion trees of around 16,000 species.

WHY IS IT SO IMPORTANT?

Every species that lives here is important, not just in its own right, but because it plays an important role in the broader ecosystem. There are predators, scavengers, seed dispersers, decomposers and pollinators, to name but a few.

They provide vital resources for the indigenous people who still live here, as well as a reservoir of potential solutions to global-scale problems. The discovery of ACE inhibitors, which are now routinely used to treat high blood pressure, was inspired by studies of the venomous Brazilian viper. Meanwhile, leaf-cutter ants, which collect leaves to fertilise the fungi on which they feed their larvae, avoid foliage rich in natural fungicides. Studying them could help us to discover new antifungal compounds.

Water vapour released from the forest creates enormous 'flying rivers' in the sky, influencing weather systems near and far. Up to 50 per cent of rainfall in the Amazon comes from the forest itself, but it also delivers rain as far south as Argentina, where it helps to support agriculture.

The bigger picture, however, centres on the rainforest's ability to store carbon. The Amazon rainforest is sometimes called the 'lungs of the Earth' because it 'breathes in' carbon dioxide and 'exhales' oxygen on a massive scale. About 123 billion tons of carbon is sequestered in the Amazon's forests and soils.

WHAT HAPPENS IF WE KEEP CUTTING IT DOWN?

The rainforest is being felled to make way for cattle ranches, and plantations of soy and other crops. Climate change, mining, timber production and the development of roads, houses and other infrastructure are also contributing to its demise.

More than 18 per cent of the Amazon rainforest has so far been destroyed, and a further 17 per cent is degraded. As their habitats disappear, many species, such as the golden lion tamarin and the South American tapir, are being driven to extinction.

Felling and burning eliminates carbon dioxide-absorbing trees, and releases their stored carbon back into the atmosphere. A study from 2021 revealed that, every year, the rainforest is now emitting around one billion tonnes of carbon dioxide more than it can absorb. A vital carbon sink is turning into a carbon emitter.

The destruction of the Amazon rainforest is fuelling climate change, and now scientists fear it is close to a tipping point, beyond which it will be unable to generate its own rainfall and support its ecosystems. Parts of the rainforest could morph into fire-prone, arid savannah. With few trees, the carbon-sequestering ability of this land would be further eroded, with negative repercussions for climate change.

5 WEIRD AND WONDERFUL ANIMALS OF THE RAINFOREST

Northern glass frog

This tree frog has translucent skin on its belly, which makes its internal organs clearly visible from underneath. Elsewhere its skin is pale green, camouflaging it amidst the forest's foliage.

Jesus Christ lizard

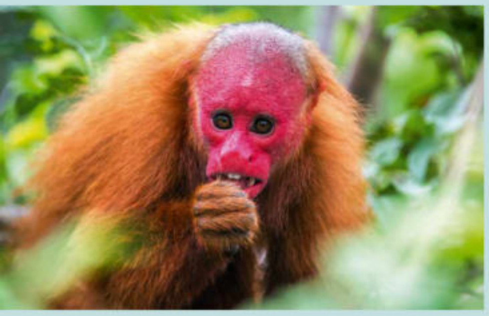
Famed for its ability to run on water, when its hind feet slap the surface, they create air pockets which help to prevent it from sinking. It can reach speeds of up to two metres per second, for distances of up to four metres.

Pink river dolphin

This freshwater cetacean is the largest species of river dolphin. They are born grey and acquire their pink colour with age. Their final hue is influenced by many things, including behaviour, diet and how close their capillaries are to the skin.

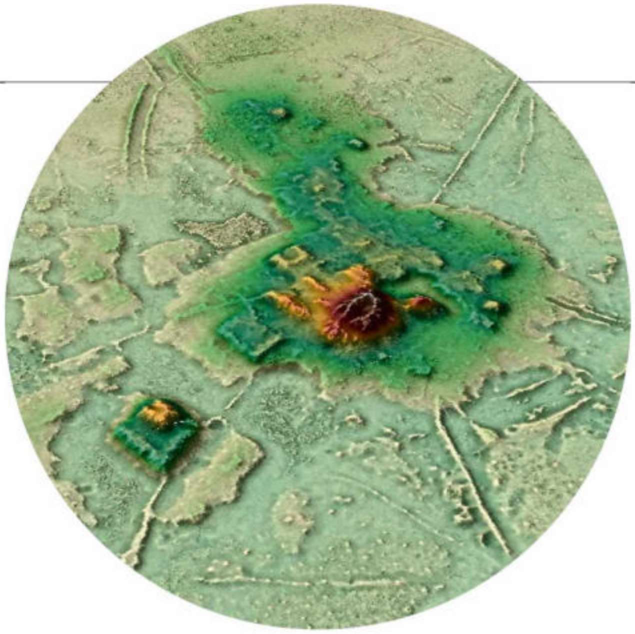
Hoatzin

Hoatzins are surely the weirdest Amazonian birds. Chicks have claws on their wings that they use to climb trees. Adults ferment vegetation, much like a cow, albeit in a specialised crop. It gives them a manure-like smell, hence their nickname, the stinkbird.



Uakari

No, uakari monkeys haven't been washing with beetroot, but the healthiest males do have the reddest faces. Females seem to know this, and choose their mates based on how red their face is. And who says beauty isn't skin deep?



HOW MUCH OF THE AMAZON IS STILL UNEXPLORED?

Trekking through the dense, intact rainforest is not easy, so parts of the Amazon rainforest remain unexplored. No one knows exactly how much is unchartered, but technology is helping researchers to study these hard-to-reach areas.

Scientists flew a remote sensing device over part of the Bolivian Amazon, using a laser to map the land. The images, released last year, revealed the presence of two ancient settlements, complete with conical pyramids, earthen buildings and artificial terraces, surrounded by a network of raised causeways (pictured above). People probably lived in the areas around the terraces, and used the causeways to get around. There were also reservoirs and canals.

The site confounds the prevailing narrative which dictates that before the Europeans arrived, the Amazon was a pristine wilderness, unchanged by the indigenous populations. Instead, it's now thought the land was modified by the Casarabe culture, who lived here between 500 and 1400 AD. It's yet another reason to study and preserve the Amazon.

> "The images revealed the presence of two ancient settlements"

NICK GARBUTT/NATUREPL.COM, GETTY IMAGES X5, H PRUMERS/BETANCOURT ET AL

CAN THE AMAZON RAINFOREST BE REGROWN?

It's better not to cut it down in the first place, but given time, tropical rainforests can sometimes regenerate. According to one study of rainforests across three continents, soil takes around 10 years to regain its original status, plant and animal biodiversity takes around 60 years, and overall biomass takes around 120 years. This is largely due to a phenomenon called 'secondary succession', where nearby pockets of forest and flora help to fuel new growth. Left alone, some tropical forests can achieve around three-quarters of their old-growth status in just 20 years.

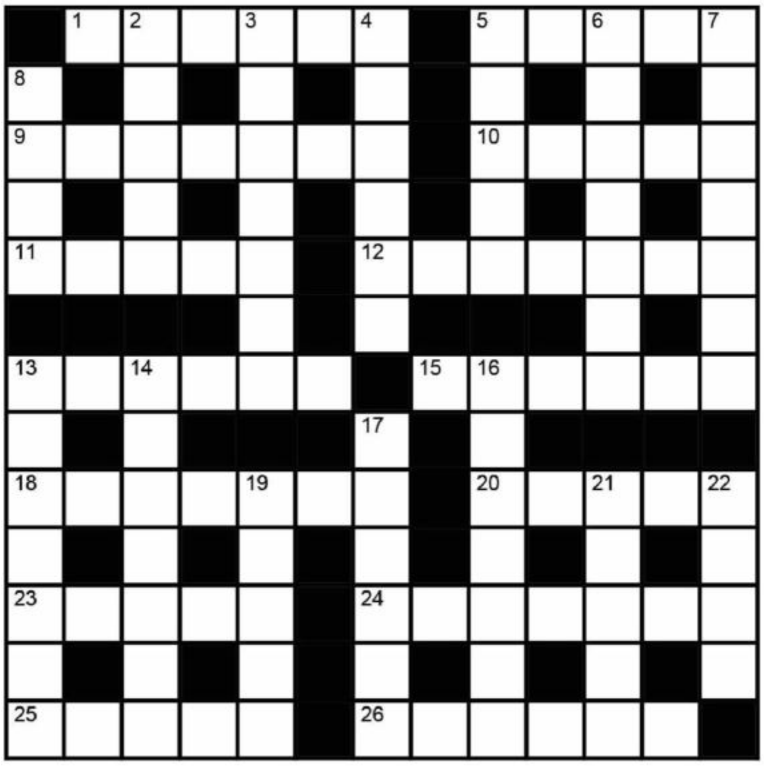
It's a better approach than planting new trees. The same study found that natural regeneration outperforms restoration planting in terms of biodiversity, recovering nutrients and mitigating climate change. This is only possible, however, if there is enough flora and fauna nearby to seed the change. Brazil is home to around 60 per cent of the rainforest. It's promising, then, that at the COP27 climate summit in Egypt's Sharm El Sheikh, Brazil's recently-elected president, Luiz Inácio Lula da Silva promised to stop all deforestation and degradation in the Amazon by 2030. SF

DR HELEN PILCHER

Helen is a freelance science writer. Her latest book is Life Changing: How Humans Are Altering Life On Earth *(£10.99, Bloomsbury Sigma).*

CROSSWORD

PENCILS AT THE READY!



ACROSS

1 Son set my new arrangement (6)
5 Quiet, back in tunnel (5)
9 A Catholic peer reveals story (7)
10 City gent has one left (5)
11 Assessed trade incorrectly (5)
12 Watch former pupil and wait (7)
13 Sample treats, prepared a different way (6)
15 Do without, on behalf of self-image (6)
18 Terribly keen to put limit on bone (7)
20 Redesigned flat incorporates universal defect (5)
23 Distinguish your head on screen (5)
24 Hermit cites a problem, catching cold (7)
25 Calling in about revolutionary (5)
26 Rush around a river city (6)

DOWN

2 Cathy travelled in boat (5)
3 Turned off, getting front of locomotive to move slowly (7)
4 Doctor into different proposal (6)
5 American uncle on huge island (5)
6 A great disruption about liberal, unconfined (2,5)
7 Time to join messenger, old fruit (7)
8 Just blonde (4)
13 Grab bag, rising to have a break (4,3)
14 Explosive answer about varnish (7)
16 Bureau right for police constable (7)
17 Big impression made by bad diver? (6)
19 Publicly denied about river (5)
21 Say spread hasn't started (5)
22 Sensitivity gets nailed, by the sound of it (4)

ANSWERS For the answers, visit **bit.ly/BBCFocusCW**
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NEXT ISSUE

DOWN ON THE FARM

Meet the robots that are changing the face of agriculture.

PETER ADAMS

PLUS

JUICE: READY FOR TAKE-OFF

After numerous setbacks due to the COVID pandemic, the mission to explore Jupiter's moons is finally set to launch.

PHOBIAS EXPLAINED

What causes them? Are they a brain disorder? And can you inherit them?

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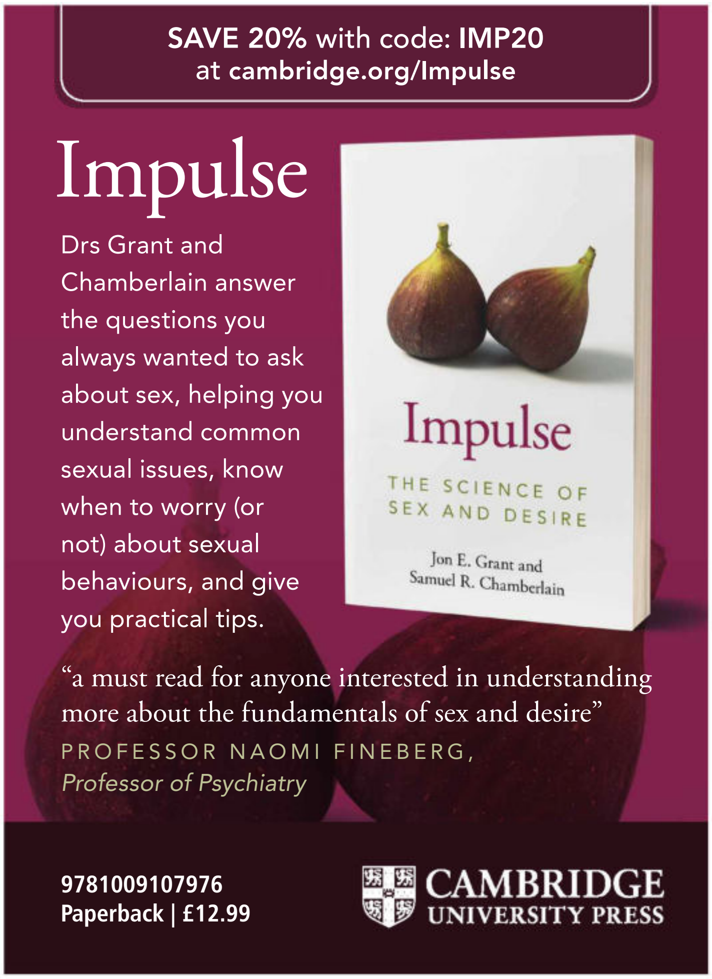

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POPCORN SCIENCE

Is hyperspace travel possible?

When will we be zipping round the cosmos like Baby Yoda and co?

by **STEPHEN KELLY**

Hyperspace travel – the ability for spaceships to travel as fast as the speed of light – is an integral part of the *Star Wars* universe. The new series of *The Mandalorian*, for instance, would be quite a different show if Mando and Grogu had to wait 6,000 years to fly from one planet to the next. But it does raise the question of just how feasible such technology is. Will we ever attain the ability to travel vast distances across space without having to burn through generations of astronauts? Or are we just marooned in our corner of the Galaxy?

ADVENTURES IN
HYPERSPACE
A SCIENCE-FICTION STORY

To answer that, Prof Patrick Johnson, author of *The Physics Of Star Wars*, needs to be clear on what, exactly, hyperspace travel is. "If we're talking about the idea that spaceships in *Star Wars* accelerate forward as fast, or faster than, the speed of light, then that is not plausible," he says. "The speed of light is the speed limit of the Universe. Once you travel faster than light, cause and effect begin to break down. You could feasibly view an event happening five light-years away, travel faster than the speed of light towards it and get there before it happens. It's basically time travel."

A more realistic option, says Johnson, is that instead of ships in *Star Wars* accelerating at the speed of light, hyperdrive technology enables them to create a wormhole in order to travel from one point in space to another. "It would be like folding a piece of paper and punching a hole through it so an ant can get to the other side," he says. It would also explain why, in certain hyperspace sequences in *Star Wars*, the ships look like they're travelling through a blue tunnel. (Although, of course, there are also other scenes, such as Vice-Admiral Holdo flying a ship at light speed through another ship in *The Last Jedi*, that lend strength to the accelerating theory).

The problem with creating a wormhole, says Johnson, is that no one knows how to do it; it's more theoretical than practical. "It would perhaps be easier to find a pre-existing wormhole and just hope it leads to somewhere you want to go," he says. "As for creating one, that would take decades' worth of human energy. And that's before we figure out how to target a particular location."

Johnson also insists that any wormhole created would have to be far away from Earth. "Going back to the paper analogy, it's not going to end well for the ant if it happens to be in the spot where the pencil bursts through. You would need an empty, unoccupied part of space, along with incredibly complex calculations and some sort of up-to-date star map, to ensure that the planet you're going to is in the right place."

At this stage, both options seem as unlikely as each other, which means that we are stuck in our Solar System for the foreseeable future. But Johnson lives in hope that, even if we can't accelerate at light speed, we can develop ways to travel long distances across the Galaxy.

"Without hyperdrives, I'd say our best bet for getting far, far away in a reasonable amount of time is solar sail technology," he says. "These would operate like wind sails, but instead use the light from a star to push the ship forward and essentially give it an unlimited supply of fuel. The acceleration would be small at first, but after 10 years you could get up to around 20 per cent of the speed of light, which is very good."

Promising – but we wouldn't book that holiday to Tatooine just yet. **SF**

SALTY

VERDICT
It doesn't matter how strong the force is with you, hyperspace travel is just not possible in our Universe.

---

by **STEPHEN KELLY** *(@StephenPKelly)*
Stephen is a culture and science writer, specialising in television and film.

ILLUSTRATION: MARK FRUDD

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